

WEST AFRICAN CACAO RESEARCH INSTITUTE



ANNUAL REPORT

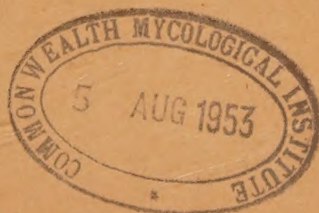
April, 1950 to March, 1951

TAFO, GOLD COAST

Published on behalf of the West African Cacao Research Institute by the
Crown Agents for the Colonies, 4, Millbank, London, S.W.1.

1953

Price 5/-



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WEST AFRICAN CACAO RESEARCH INSTITUTE.

MANAGING COMMITTEE, 1950-51.

Chairman :

W. B. L. MONSON, Esq., C.M.G. ... Chief Secretary, West African Council.

Members :

NANA WIAFE AKENTEN II. ... Offinsuhene, Ashanti, Gold Coast.

A. G. BEATTIE, Esq. ... Director of Agriculture, Nigeria.

H. J. N. CHAPMAN, Esq. ... Principal Assistant Secretary,
Ministry of Agriculture and
Natural Resources, Gold Coast.

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S. D. ROSS, Esq. ... Director of Agriculture, Gold Coast.

J. WEST, Esq. ... Director of Cacao Research,
West African Cacao Research
Institute.

WEST AFRICAN CACAO RESEARCH INSTITUTE.

SENIOR STAFF AS AT 31ST MARCH, 1951.

Director	...	...	J. WEST, B.S.A., A.I.C.T.A.
Deputy Director	...	...	A. PICKLES, M.Sc., A.I.C.T.A.
Division of Entomology			J. NICOL, B.Sc. (For.). R. G. DONALD, B.Sc., A.I.C.T.A. H. R. MAPOTHER, B.A., B.Sc., A.R.I.C. F. E. DECKER.
Division of Plant Path- ology and Botany.			C. L. F. HUNTER, B.Sc., Ph.D. J. F. ARCHIBALD, B.Sc. (Hort.). H. H. ROGERS, B.Sc., Dip.Agr.Sci.
Division of Soil Science and Chemistry.			J. A. R. MACLEAN, Ph.D., B.Sc., A.R.I.C. S. N. ADAMS, D.Phil., B.A.
Division of Agronomy	...	...	R. J. BENSTEAD, N.D.A., C.D.A. R. WICKENS, B.A., Dip.Agric., D.T.A. S. E. NTIM-KWAFO.
Secretary	...	...	G. H. NEAL, F.R.S.A., F.I.P.A.
Construction Engineer	...	...	C. ALDERSON, D.S.O., E.D., B.Sc., M.Inst. M. and C.E.

WEST AFRICAN CACAO RESEARCH INSTITUTE.
ANNUAL REPORT : 1st APRIL, 1950 TO 31st MARCH, 1951.

I. POLICY AND ORGANIZATION.

SENIOR STAFF CHANGES.

The shortage of senior scientific staff created a serious problem and, while it has been possible to recruit new staff, the number of resignations during the year has exceeded the number of new appointments. In particular, the resignation of Mr. Todd on the 15th March, 1951, leaves the Institute without a Virologist and with no immediate prospect of filling this key position. Other officers who left the Institute's service during the year are Messrs. G. Williams, A. H. Strickland and A. J. P. Goodchild (Entomologists), H. Owen (Plant Pathologist) and T. Wasowicz (Soil Chemist).

Mr. A. Pickles, formerly Senior Entomologist in the Department of Agriculture, Nigeria, assumed duty as Deputy Director on the 15th April, 1950. Dr. C. L. F. Hunter was appointed on contract as Mycologist on the 6th April, 1950, and Mr. H. H. Rogers (Plant Breeder) and Dr. S. N. Adams (Soil Chemist) were appointed with effect from the 21st September, 1950, and 25th January, 1951, respectively. Mr. S. E. N. Kwafo, formerly Senior Technical Assistant in the Division of Agronomy, returned from a course of study in the United Kingdom and was appointed Assistant Specialist (Station Manager) on the 29th July, 1950.

MANAGING COMMITTEE.

The Managing Committee met at Tafo in November, 1950, and February, 1951. The Committee has appointed a standing Sub-Committee, to be known as the Technical Sub-Committee, consisting of the Directors of Agriculture of Nigeria and the Gold Coast, with the Director of Cacao Research as Chairman and with power to co-opt specialist advisers. The duties of the Sub-Committee are to consider all technical matters with which the Managing Committee and the Institute are concerned and to present their considered opinion on such matters to the Managing Committee.

TOURS.

The Director visited Nigeria in March, 1951, for consultations with the Director and staff of the Department of Agriculture, with special reference to research on black pod disease and surveys of mealybugs and their parasites in that country.

VISITORS.

The Minister of Agriculture and Natural Resources of the Gold Coast, the Honourable A. Casely-Hayford, M.L.A., visited the Institute on the 12th and 13th March, 1951, and examined in some detail the field and laboratory work in progress.

Members of the staff of the Gold Coast Department of Agriculture were frequent and welcome visitors. The Director and Deputy Director (Cocoa Industry) of the Department, accompanied by the Assistant Directors, spent the greater part of the 22nd March, 1951, at the Institute in the course of their annual conference. It is intended that similar visits should be an annual fixture. The Agricultural Advisory Committee of the Eastern Province of the Gold Coast also met at the Institute on the 28th April, 1950, and visited the laboratories at experimental grounds in the course of their meeting.

Regular visits by officers of the Nigerian Department of Agriculture are less easily arranged, but three officers, in addition to those attending Managing Committee meetings, were able to visit the Institute in the course of the year.

An official Agricultural Mission from Brazil included the Institute in their itinerary in October, 1950, and the United Kingdom Parliamentary Delegation to the Gold Coast Legislative Assembly were shown round the Institute on the 27th March, 1951.

Other visitors included representatives of commercial and manufacturing interests from the United States and United Kingdom and members of universities, colleges and other research organisations in the Gold Coast and the United Kingdom and other countries.

Visits by farmers, school teachers and students, which are organized by the Department of Agriculture, continued to be popular and visits by one or more such parties are now almost a daily occurrence.

CONSTRUCTION.

The main construction programme was virtually completed by the end of the financial year, when the two remaining bungalows and the recreation centre, shown as under construction in the last Annual Report, were ready for use.

During September, 1950, the reservoir was filled and completion of the filtration plant enabled the water supply system to be tested towards the end of March, 1951. The water supply system has proved entirely satisfactory and should be in full operation in the near future.

SWOLLEN SHOOT DISEASE.

Evidence continues to accumulate on the value of cutting out in the treatment of swollen shoot outbreaks and the danger of leaving such outbreaks untreated.

In an area of $8\frac{1}{2}$ acres where no control of swollen shoot disease is attempted and where replanting at stake is practised in all open spaces formed by the death of the trees (Rate of Destruction Plot), the yield declined from $8\frac{3}{4}$ loads to $1\frac{1}{4}$ loads per acre over a period of five and a half years. By contrast, in another area where diseased trees are removed as soon as symptoms are observed and where seed

at stake is planted in the spaces so formed (Old Station), the yield at first dropped owing to the reduction in the productive tree population but increased again as young trees came into bearing and is now rapidly approaching the same level as before the onset of disease.

SYSTEMIC INSECTICIDES.

In addition to the work being carried out by the Institute on systemic insecticides, a team provided by Messrs. Pest Control Limited commenced work as indicated in the Annual Report for 1949-50. The Institute provided laboratory and living accommodation for the members of the team, and placed an area of cacao at their disposal for their experiments. A large part of the cost of the work of the team is being met from the funds of the Institute.

II. VIRUS RESEARCH.

NEW VIRUS STRAINS.

Two new strains of cacao virus have been discovered during the year 1950-51. The first was noted at Saalman in the Akim Abuakwa district and it appears to be quite common in this area. The leaf symptoms are confined to only one half of the leaf and take the form of a yellow mottling which covers practically the whole of one side of the mid-rib, and which tends to form a false sickle leaf. Symptoms on pods, twigs, chupons and roots are unknown.

The second strain was located at Tepa in Ashanti. This outbreak was small, comprising about 30 to 40 trees, and it was found to be approximately 40 miles from any other known outbreak. Like the Saalman virus the symptoms were confined to the leaves, with the young flush leaves displaying a red mottling between the lateral veins, and the mature leaves having a flecking of the tertiary veins. Very often these symptoms occurred on one side of the mid-rib only.

In both the above instances the infected trees did not seem to be debilitated when compared with the surrounding healthy trees. The Tepa virus in some instances bore a resemblance to the Alaparum virus of Nigeria.

RATE OF SPREAD AND EFFECT ON YIELD OF VIRUS 1A.

This experiment is a continuation of the one recorded in the Annual Report for 1949-50. The unrestricted spread of virus 1A has now been recorded for $5\frac{1}{2}$ years and whereas in August, 1945, there were only 31 per cent. of the trees diseased on the $8\frac{1}{2}$ acre plot, in March, 1951, the percentage had risen to 92.2 per cent., whilst the yield in the same time had decreased from $8\frac{3}{4}$ loads to 1.2 loads per acre.

Tables 1 and 2 give the records of the annual rate of spread and annual yields respectively.

TABLE 1.

Percentage increase of infection of healthy trees by virus 1A on the Rate of Destruction Plot, Tafo.

Year.	Total trees infected.	Per cent.
1945	1,450	31
1946	2,132	46
1947	2,967	64
1948	3,717	80
1949	4,144	89
1950	4,257	92
1951	4,270	92.2

TABLE 2.

Decrease in yield per acre of the Rate of Destruction Plot, Tafo.

Year.	Total lbs. wet beans.	Loads per acre.
1945	4,389.5	8.75
1946	3,038.3	6.13
1947	2,276.8	4.5
1948	1,931.5	3.8
1949	881.1	1.7
1950	600.6	1.2

Since 1947 the local practice of replanting with beans at stake has been carried out under the devastated mature cacao. About 18,000 seedlings have so far been planted of which 348 had shown virus infection by March, 1951. Five sub-plots of $\frac{1}{4}$ acre have been demarcated and spot-planned for a study of the movement of the mealybug (*P. njalensis*, Laing) through the seedlings.

THE FIELD PROTECTION TEST.

The main object and layout of this experiment was recorded in the Annual Report for 1949-50 and it has been carried out on the same lines as then reported. Again the main observations have been concerned with the natural spread of the virulent strain from the perimeters into the sub-plots.

Table 3 gives the annual percentage spread of infection into both the mild strain immunized and the Control plots.

TABLE 3.

Rate of Spread of Virulent virus 1A.

Year.	No. of trees infected (per cent.).	
	Untreated Control.	Graft-infected with mild virus.
1947	2.48	3.7
1948	9.52	4.79
1949	19.25	9.15
1950	47.41	15.9

It will be observed from the above data that the number of trees in the Control plots showing virulent infection has greatly increased during the past year whilst the spread of virulent virus infection into the plots which were protected by prior infection with mild virus has been retarded. Transmission tests are being carried out to determine whether or not the virulent virus is present in the mild infected trees which do not show virulent virus symptoms. Preliminary results on similar trees in the Rate of Destruction Plot have shown that transmission of the virulent virus can be obtained from trees previously infected with mild virus when only one vector is used as the transmitting agent.

The yield comparisons between the trees infected with mild virus and the healthy Control trees are given in Table 4. These yields were obtained from two sets of eight sub-plots containing respectively healthy and mild-strain infected trees. Each sub-plot consisted of nine trees; all of which in the first instance were at least one tree removed from the nearest incidence of virulent strain infection; otherwise the trees were selected at random.

TABLE 4.

Harvest Season.	Mean yield of eight sub-plots.	
	Apparently healthy.	Mild-strain infection.
1947-48	126.1	124.4
1948-49	164.9	166.8
1949-50	172.4	152.9
1950-51	162.9	136.9

It will be noted that the yield for 1950-51 dropped in both treatments. However, there was a slightly greater reduction of yield

in the case of the mild-strain infected trees but by a simple analysis of variance the differences between the yields was not significant ($P = 0.05$).

RESISTANCE TO VIRUS 1A.

Tests for comparative resistance to virulent virus 1A have again been confined to cacao of the Upper Amazon Forastero origin. The material used in these experiments was again, as in the 1949-50 season, only available as beans or seedlings of unknown male parentage, the material, therefore, was again not genetically pure.

As in earlier Reports, progenies resulting from the crossing of Nanay and Parinari types showed a significantly greater resistance to infection by vectors, when the vectors were feeding on the bean cotyledon than did the Control plants of West African Amelonado.

The techniques used in these tests were the same as those described in the Annual Report for 1949-50, and during the past year 4,476 plants were used in the resistance trials.

Upper Amazon cacao was again found to be more resistant and more tolerant to infection than the West African Amelonado. The greater resistance is demonstrated in Table 5 where it is shown that fewer beans of the Upper Amazon type became infected than did the Amelonado beans. The greater tolerance is again shown by the more vigorous growth of the infected Upper Amazon plants.

TABLE 5.

Comparison of Rate of Infections of Upper Amazon and Amelonado with virus 1A.

Selection and Stand.	Type.	Number of pods treated.	Total number of beans used in either Amazon or Amelonado Controls.	Rate of infection of beans.*	
				Amazonian.	Amelonado Controls.
T62/977	Amazon Nanay	7	124	44/120	94/120
T63/761	Amazon Parinari × Nanay	5	134	74/132	100/129
T63/883	" " " "	7	123	57/107	111/123
T79/414	" Nanay × Parinari	6	160	77/155	120/158
T82/998	" " " "	8	187	95/170	151/180
T92/791	" Nanay	6	173	70/145	152/170
T92/880	" "	6	127	66/124	103/123
T92/1703	" "	7	178	82/167	143/170
T92/1704	" "	10	270	139/251	199/262
T62/1048	" "	6	150	58/141	96/147
T72/1523	" Nanay × Iquitos	6	174	78/164	120/165
T79/1151	" " × Parinari	7	185	67/175	116/181
T82/1026	" " " "	5	114	55/113	70/112
T86/955	" Parinari	6	120	64/111	69/113

* Beans which did not germinate are not included.

As can be observed from Table 5 the resistance was significantly greater in the selections Nanay × Nanay, Nanay × Parinari than it

was in Parinari $\times$ Parinari. This is in accordance with the results that were obtained in the 1949-50 season. These more stringent tests are continuing to determine whether a high degree of resistance or absolute immunity exists.

ALTERNATIVE HOST PLANTS OF CACAO VIRUS.

Alternative host work during the past year has followed the same lines as in previous years (Annual Report for 1949-50). In the past year, however, it has been proved that *Corchorus tridens*, a member of the family Tiliaceae, is susceptible to virus 1A. This is the first species to be found susceptible outside the Sterculiaceae and Bombacaceae families. *Cistanthera papaverifera* A. Chev. and *Desplatia lutia* A. Chev., also of the family Tiliaceae, have so far shown a resistance to the virulent virus 1A.

It has been shown that *Sterculia rhinopetala*, *S. tragacantha* and *Ceiba pentandra* are susceptible to virus 1A, Nkawkaw, Mampong and Bosumuosu viruses, whilst *S. rhinopetala* is also susceptible to the Bosumtwé virus and *Ceiba pentandra* to the Amafie virus. *Cola chlamydantha* and *Adansonia digitata* are susceptible to virus 1A and Bosumuosu viruses whilst *Pterygota macrocarpa* and *Corchorus tridens* have so far only shown susceptibility to virus 1A, which proved fatal to *Corchorus tridens*.

The availability of virus 1A in *S. rhinopetala*, *S. tragacantha* and *Adansonia digitata* appears to persist at a fairly high level for the first three months after bombardment and thereafter to fall rapidly in the first two species and more slowly in the latter. As was expected, the availability of the Bosumuosu virus in *Cola chlamydantha* persisted at a high level during the whole of the testing period and the test bean infection rate was higher than that for *C. chlamydantha* infected with virus 1A. In *Adansonia digitata* persistently high rates of test bean infection were obtained with virus 1A although comparatively lower rates of infection were recorded when the Bosumuosu virus was used. Nearly 8,197 test bean plants were used for this experiment.

VIRUS-HOST RELATIONSHIP.

The history of virus infection in seedlings of *Ceiba pentandra* has been continued (Annual Report, 1949-50).

Five *Ceiba pentandra* seedlings were bombarded with vectors infected by virus 1A in 1949. Two months after the bombardment, patch-grafts were taken from three of them and grafted on fifteen healthy *C. pentandra* seedlings. Six months later periodical back-testing was carried out on the original five infected seedlings and back-testing on the grafted seedlings was started when the bombarded seedlings were receiving their third back-testing.

The results of the transmissions are given in Table 6.

TABLE 6.

Plant No.	1st test.	Interval in months.	2nd test.	Interval in months.	3rd test.	Interval in months.	4th test.
Bombarded							
<i>Ceiba pentandra</i>							
70/1	0/35	1	0/95	2.0	0/53	4.5	0/31
70/3	0/36	1	0/49	2.0	9/43	4.5	0/25
70/5	0/47	1	0/72	2.0	0/71	4.5	0/29
70/7	0/39	1	0/51	2.0	5/56	4.5	0/20
70/9	0/47	1	0/38	2.5	1/74	4.0	0/36
					1st test		2nd test
<i>Ceiba</i> No. 1 Patch-grafted from 70/1					0/74	4.0	0/7
" " 2 " " " "	" " " "	" " " "	" " " "	" " " "	0/82	4.0	0/7
" " 3 " " " "	" " " "	" " " "	" " " "	" " " "	0/56	4.0	0/31
" " 4 " " " "	" " " "	" " " "	" " " "	" " " "	0/32	4.0	0/28
" " 1 " " " "	" " " "	" " " "	" " 70/5	" " " "	0/105	4.0	0/9
" " 2 " " " "	" " " "	" " " "	" " " "	" " " "	20/108	4.0	0/22
" " 3 " " " "	" " " "	" " " "	" " " "	" " " "	14/90	4.0	0/25
" " 4 " " " "	" " " "	" " " "	" " " "	" " " "	0/54	4.0	0/13
" " 1 " " " "	" " " "	" " " "	" " 70/7	" " " "	0/40	4.0	0/13
" " 2 " " " "	" " " "	" " " "	" " " "	" " " "	0/36	4.0	0/39
" " 3 " " " "	" " " "	" " " "	" " " "	" " " "	0/26	4.0	0/33
" " 4 " " " "	" " " "	" " " "	" " " "	" " " "	0/66	4.0	0/36

Plants were coppiced after each test and the new shoots used for the next back-tests.

Alternative host plants which proved to be infected in 1948 have been further tested for virus availability and the results of the transmissions are given below.

TABLE 7.

Host species.	1st Retest.	Rates of host infection.			3rd Retest.
		Average interval in months.	2nd Retest.	Average interval in months.	
<i>Ceiba pentandra</i> ...	1/20	3.25 for 16 plants	0/16	6 for 8 plants	0/8
<i>Sterculia tragacantha</i> ...	0/2	1 " 2 "	0/2	6 " 2 "	0/2
<i>Sterculia rhinopetala</i> ...	0/7	1 " 7 "	1/7		
<i>Adansonia digitata</i> ...	0/3	1 " 3 "	1/3	6 " 3 "	0/3
<i>Cola cordifolia</i> ...	0/8	4.88 " 8 "	0/8		
<i>Bombax buonopozense</i>	0/3	1 " 3 "	0/3	6 " 3 "	0/3
<i>Erythrina baterii</i> ...	0/1	8 " 1 plant	0/1		

Each retest was carried out on the shoots which developed after the plants had been coppiced. This treatment is conducive to virus build-up in the plants.

FIELD WORK.

During the past year field work has been confined to testing for virus in alternative hosts on the W.A.C.R.I. Station.

Only one positive transmission was obtained from a *Ceiba pentandra* and this gave one transmission out of 449 tests. Many of the other plants tested, although showing a chlorotic condition of the leaves, failed to give any transmissions of the cacao virus.

The results of this work are tabulated below.

TABLE 8.

Plant species	Test beans used.	Positive transmission.	Part of plant tested.
22 <i>Ceiba pentandra</i> ...	2,725	1	Fresh shoots
40 " " ...	1,534	—	" "
5 <i>Cola cordifolia</i> ...	341	—	" "
1 <i>Sterculia tragacantha</i> ...	154	—	Twigs and leaves
1 <i>Riciodendron africanum</i>	36	—	Roots and twigs
1 <i>Terimalia superba</i> ...	18	—	Leaves and twigs
1 <i>Carica papaya</i> ...	36	—	Leaves and stem tip
	4,844		

CHEMOTHERAPY.

The investigations on the virus disease of cacao have been directed towards inactivation of the virus in the living plant tissue or to rendering the plants immune to virus infection by chemical treatment. The instability of the cacao virus seems to offer good possibilities of chemical inactivation. This instability is suggested by the fact that, unlike many other viruses, it becomes inactive in expressed sap and macerations of infected plant tissue.

Four different techniques have so far been used for this work: 1, treatment of budwood; 2, root absorption; 3, injection of seedlings; 4, treatment of bean cotyledons, and two chemical treatments are also being used. In one series of experiments the plants are being treated with the chemicals before infection with the virus for the determination of the possibility of developing an immune plant, and in the second series the plants are being chemical treated after infection with virus 1A. This latter series of experiments is to determine the possibility of virus 1A inactivation by the use of chemicals.

The experiments so far have shown no complete inactivation of the cacao virus 1A, but in certain instances there is an indication of

the reduction in virus symptom expression which may be due to partial inactivation. These indications of possible inactivation are being followed by varying the concentration of chemical used and the time of chemical treatment in the first instance and later by using derivatives of the chemical compound under trial. To date, the experiments have necessarily been carried out on a purely empirical basis with the main aim being the testing of numerous chemicals to observe their physiological reaction as well as the action on the virus as shown, in the latter instance, by vector transmission and symptom expression.

Table 9 gives the chemical compounds that have so far been used with their concentrations, and method of application.

TABLE 9.

Chemical treatment of cacao for virus inactivation.

Chemical.	Percentage concentrations used.	Treatment.
8-Hydroxyquinoline	0.025, 0.0083, 0.00415, 0.002	Root absorption and budwood treatment
1.5: Diamino-Anthraquinone	0.025	"
Hydroquinone	0.05, 0.025, 0.00625	"
Quinhydrone	0.01, 0.05, 0.025, 0.00625	"
<i>p</i> -Nitrophenol	0.1, 0.05, 0.015, 0.00625	"
Sodium Selenate	0.001	"
Lissalamine A. (50% C.T.A.B.)	(parts per parts of water) 1/20,000, 1/40,000, 1/80,000	"
Colchicine	0.05	"
Paludrine Hydrochloride	0.1	"
2.4: Dichloro-phenoxy-acetic acid	0.05, 0.00835	"
Urea	0.1, 0.05	"
Malachite Green	0.01, 0.025, 0.0025	"
Iodine	0.02, 0.05, 0.005	"
Zinc Sulphate... ..	0.01, 0.005	"
Potassium Permanganate	0.01	"
Maltose	2.0	"
Mercuric Potassium iodide	0.005, 0.001	"
Benzoic acid	0.01, 0.005	"
2.4: Diamino-azobenzene	0.01, 0.005	"
Sodium thiosulphate... ..	0.005, 0.001	"
Sulphanilamide	0.05	"
Sulphapyridine	0.016	"
Sulphathiazole	0.016	"
Sulphadiazine... ..	0.016	"
Sulphaquandine	0.016	"
Sulphamerizine	0.016	"
Succinylsulphathiazole	0.016	"
Phthalylsulphathiazole	0.016	"
<i>p</i> -Toluine sulphonamide	0.016	"
Calcium chloride	0.2, 0.1	"

The majority of the chemical compounds listed above have been used for both treatment of budwood and for the root absorption technique, whilst only the sulpha drugs, so far, have been used for injection work at the same concentrations as those used in the budwood and root absorption trials,

It was found that the phytotoxicity of *p*-nitrophenol, even at very low concentrations, was such that this chemical compound would be of little use for the treatment of cacao. Many of the other compounds produced a phytotoxic condition at the higher concentrations used but a satisfactory plant reaction was obtained at the lower concentrations. Treatment of second flush seedlings with colchicine by the root absorption method produced a prolonged period of dormancy which in some instances has lasted for six months. There seemed to be little or no action on the virus, as shown by vector transmission, or on the genetical make-up of the plant. This latter failure may be due, in part, to the incompatibility which exists between tanins and colchicine.

This work is now continuing on a more intensive scale since the initial difficulties have been overcome in many instances and the necessary modifications in techniques have been applied.

III. CAPSID RESEARCH.

GENERAL.

Macromischoides Field Experiment.

The majority of the trees continue to show extremely good growth and the advantages of line planting are amply demonstrated. The area has proved very useful as testing ground for new insecticides and for the methods of applying them.

2,379 pods were harvested, a small number of which were damaged by rodents. This is a remarkably good crop from trees which are only five years of age.

A small outbreak of swollen shoot involving five trees was found. The diseased trees were cut out immediately the symptoms were noticed and the outbreak has been successfully controlled.

Macromischoides Area Extension.

Because of the great value of the original area for entomological experiments it was decided to make an extension so that a supply of young trees would be available for future work. $3\frac{1}{2}$ acres were planted up in June, 1950, as $\frac{1}{2}$ -acre plots with a tree spacing of 5 ft. $\times$ 5 ft. Unfortunately, germination was not good and a considerable amount of supplying had to be done. Subsequent growth was satisfactory.

Regeneration of Capsid Pockets.

The results obtained from the capsid "pocket" plots coppiced in 1946 have shown that it is possible to regenerate such heavily damaged cacao provided capsids can be eliminated from the resulting

vigorous young growth. The use of "KUMAKATE" (2.5 per cent. D.D.T. emulsion) ensures this and it was decided to lay down a large scale field test.

A suitable area of heavily damaged cacao, about one acre in extent, was available in Blocks K and L of the Square Mile and coppicing was done in July, 1950, after the establishment of *Glyricidia* and tree cassava shade.

722 trees were cut and 89 per cent. produced chupons. All the vacancies were filled with transplanted seedlings. Chupon growth was good and at the end of the year the average height of the chupons was about five feet.

Forest Reserve Cacao Plots.

The two small cacao plots in the Pra-Anum Forest Reserve were visited during May, 1950. The cacao in both plots is growing well. Flowering is common, but considerable cherelle wilt, probably due to the dense planting, occurs.

No capsids were seen and the only signs of damage were a few well-healed lesions of which none appeared to be infected with *Calonectria rigidiuscula*. A certain amount of thinning was carried out.

CHEMICAL CONTROL.

It has been shown in previous Annual Reports that the control of capsids on young cacao is readily obtained by the technique of hand painting with D.D.T. emulsion. There comes a time, however, when young cacao has grown out of hand-reach but has not grown sufficiently to close the canopy and give conditions suitable for dusting. This interim period is in approximately the five to ten-year-old stage. Such young, vigorously growing trees afford conditions attractive to capsids and it is imperative that they be protected. With this end in view, two lines were pursued to investigate the possibility of using (a) smokes and (b) liquids. Both D.D.T. and B.H.C. were employed.

(a) *Smokes.*

It appeared at first sight unlikely that conditions suitable for the use of smokes would occur. Accordingly, observations were made in the wet and dry seasons on the behaviour of liberated smoke. In the first instance, these have related only to the physical performance of smokes and not to their insecticidal properties.

The site chosen contained uniform mature cacao giving good smoking conditions. Readings of temperature were taken in the canopy and about two feet above ground level. Relative humidity was measured at the latter height. Readings were taken at 6 a.m., 2 p.m. and 6 p.m.,

Observations were made for the dry season in February and for the wet season in May-June.

Mean temperature and relative humidity figures are shown below.

TABLE 10.

Season.	Time.	Temperature °F.		Relative humidity per cent.
		Canopy.	Ground.	
Dry ... (February)	6 a.m.	67.8	68.7	94.0
	2 p.m.	89.9	90.0	57.0
	6 p.m.	76.8	84.0	65.5
Wet ... (May-June)	6 a.m.	72.8	73.7	92.6
	2 p.m.	85.1	85.7	75.0
	6 p.m.	80.7	81.3	89.0

These observations led to the following conclusions. At dawn in both wet and dry seasons, no temperature inversion has occurred and extremely slow vertical air movements are present. Smokes could not be used under these conditions.

In the evening, in both wet and dry seasons, slight air movement was generally present and it was consistent in direction. In many cases the smoke either drifted under the canopy or went through it and rolled along the top without rising further. This seems to indicate that a temperature inversion may take place above the canopy which blankets the air mass below. On some occasions, however, conditions were such that smoke drifted in the canopy and was held there. These conditions obtained rather more in the wet season than in the dry. On these occasions good cover was obtained by carrying the generator in a simple holder and walking slowly across the direction of air movement. Although this was possible it is not considered that the use of smokes for routine control is feasible. Since, from the observations made, conditions are not constant from day to day, it would require skilled judgment to assess whether use would be possible on any one day. This skilled judgment is not likely to be available outside a scientific establishment.

A few simple tests were, however, carried out on the insecticidal efficacy of smokes.

Capsids were placed in wire mesh cages with pods and twigs. When they had settled down, one cage was held for a given time in the smoke cloud from a D.D.T. generator and a second cage in that from a B.H.C. generator. A third cage was used as control. Three experiments were made using different times of exposure in the smoke cloud. The exposures given were 10, 20 and 30 seconds.

Counts were made after 24 hours, with the following results:—

TABLE 11.

Exposure (sec.).	D.D.T.			B.H.C.			Control.		
	Alive.	Dead.	Total.	Alive.	Dead.	Total.	Alive.	Dead.	Total.
10	24	10	34	11	17	28	11	7	18
20	28	12	40	27	13	40	35	7	40
30	23	17	40	7	33	40	28	12	40

Corrected for control mortality, the "percentage kill" figures are:—

TABLE 12.

	<i>D.D.T.</i>	<i>B.H.C.</i>
10 sec.	0%	36%
20 „	20%	23%
30 „	17·8%	75%

Even allowing for the small scope of these tests, due mainly to the difficulty of collecting adequate numbers of capsids, and for the high mortality of controls which is usual with capsids in captivity, it is evident that smokes are not effective against capsids. It would also appear, that of the two insecticides, B.H.C. is the more effective when applied as a smoke.

(b) *Spray Painting.*

Since control by hand-painting is based upon deposition of D.D.T. on the capsid resting places on the tree, a method was sought to apply the same principle to larger trees.

In the first place a brush, off-set and mounted on a handle about four feet long was used but was found to be unmanageable in cacao, since it could not be withdrawn, dipped in solution and pushed forward again due to the necessarily long handle.

To avoid withdrawal of the brush from the tree, a spraying lance was used as the handle and arranged to feed solution into the centre of a 1½-in. diameter round brush when the trigger was depressed. For the feed inside the brush both a straight forward small nozzle and a tube, blanked off at the end but containing fine apertures laterally, were employed. Both methods were found unsatisfactory as the great majority of the fluid merely ran through the side of the brush and was lost.

An arrangement of three small (¾-in. diameter) brushes mounted close together with a feed to each brush was next used. Again, most of the liquid dribbled through the brushes and was lost.

Spray painting was next attempted. For the problem in hand, a nozzle of somewhat unorthodox design was required, since a spray of narrow cone angle and containing relatively coarse droplets was necessary. Of the nozzles available at the time, one commercial

product was found to be suitable when set out of normal adjustment. Since then, however, through the courtesy of Dr. H. G. H. Kearns, of Long Ashton Research Station, small nozzles have been received which function admirably. These are used on a 4 ft. lightweight lance with trigger-valve on a knapsack sprayer. The trigger-valve is necessary in order to get quick, short bursts of droplets since the technique can in no way be termed "spraying" but is the projection of a small mass of droplets on a particular place.

A small trial on 15 trees for each treatment was first conducted. One set was treated with 1 per cent. D.D.T. emulsion; a second set with 0.35 per cent. gamma B.H.C. emulsion and a third set as control was employed. The liquid was projected at each branch union and along the twigs. The operator walked round each tree and no difficulty was experienced in reaching branches twelve feet high. At the time of test (March) capsid population was not very high.

Results obtained are shown below :—

TABLE 13.

Time (weeks).	D.D.T.					B.H.C.					Control.				
	DtN	DtA	SsN	SsA	Total	DtN	DtA	SsN	SsA	Total	DtN	DtA	SsN	SsA	Total
Pre-treatment	2	—	7	—	9	4	—	12	1	17	12	—	3	1	16
1	—	—	—	—	0	—	—	—	—	0	17	—	10	—	27
2	—	—	—	—	0	—	—	—	—	0	17	—	30	—	47
5	—	—	—	—	0	—	—	—	—	0	8	—	7	2	17
6½	—	—	—	—	0	—	—	—	—	0	4	2	4	1	11
7½	—	—	—	—	0	—	—	—	—	0	—	—	1	1	2
8½	—	—	—	—	0	—	—	—	—	0	—	—	3	3	6
9½	—	—	—	—	0	—	—	—	—	0	10	—	2	1	13
10½	—	—	—	—	0	—	—	—	—	0	16	1	—	2	19
11½	2	1	—	—	3	—	—	—	—	0	3	3	3	1	10
12½	1	—	—	—	1	—	—	—	—	0	—	—	1	—	1
15½	—	—	—	—	0	—	—	—	—	0	—	—	2	1	3
23½	6	5	—	—	11	—	—	—	—	0	—	—	1	2	3

Abbreviations :— DtN—*Distantiella theobroma* nymphs.
DtA— " " adults.
SsN—*Sahlbergella singularis* nymphs.
SsA— " " adults.

These figures show that excellent control was obtained in the case of D.D.T. emulsion for 2½ months and in the case of B.H.C. for at least five months.

A large field trial on this technique is now running.

IV. CHEMISTRY.

1. CACAO FERMENTATION.

During the past year work has been concentrated on three problems arising from the fermentation of cacao :—

- Determination of the optimum laboratory conditions for the fermentation of Upper Amazon selections.
- Development of a laboratory testing-panel technique to assess the quality of small-scale fermentation samples.

C. Examination of the relationship between the composition of the pulp and the degree of fermentation.

B and C were done in conjunction with the Agronomist and the material used was taken from 40 lb. wet bean samples fermented in baskets, following the Nigerian Department of Agriculture procedure (1).

A. Laboratory fermentation of Upper Amazon cacao.

Difficulty has been experienced in fermenting the comparatively small harvests of Upper Amazon cacao produced to date. Experiments to find the optimum conditions for single-pod fermentation of a representative selection, viz., *Nanay* T62, have been completed and it is proposed that the basic conditions should be applied to the treatment of intermediate scale and eventually of bulk samples. Experimental procedure is essentially similar to that for West African Amelonado cacao (2). Length of time and end-temperature of fermentation were, however, varied and, using two thermostatically-controlled ovens, a split-plot design in which these variables were randomised in six blocks of four treatments, was considered suitable.

Results can be summarised as follows:—

TABLE 14.
Table of Means (per cent. fully-fermented beans).

Temp.	Length of fermentation in days.				Mean.
	6	7	8	9	
T ₁	85.2	98.3 (± 4.33)	95.0	98.3	94.2 (± 2.48) S.D. between means = 9.00 (P = 0.05)
T ₂	92.2	95.8	98.4	96.6	95.8
Mean	88.7	97.1	96.7	97.4	95.0
± 2.53					
S.D. between means = ± 8.45 (P = 0.05)					
S.D. for interaction comparisons = ± 14.98					

T₁ represents the following temperature sequence:—

0- 24 hrs.	oven temp.	= 37° C.
24- 72	" " "	= 43° C.
72- 96	" " "	= 47° C.
96-120	" " "	= 49° C.
120-End of ferm.		= 49° C.

T₂ is similar for 120 hours:—

120 hrs.-End of ferm.	= 52° C.
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Difficulty in assessing the value of these results is caused by two factors:—

- (a) the uniformity low purple bean percentage in all twenty-four samples,

(b) doubt as to the exact point of division between a fully-fermented and an over-fermented bean.

Further differentiation of samples was attempted by inviting a panel of four to allot points for appearance, taste and aroma (a maximum of three points for each "quality factor"), to the unroasted beans.

Results are as follows :—

TABLE 15.
Table of means—Score for quality.

Temp.	Max. Score.	Length of fermentation in days.				Mean.
		6	7	8	9	
T ₁	36	19.0	18.7	23.3	21.3	20.5 (± 1.32) S.D. = 8.43 (P = 0.05)
T ₂	36	23.0	24.0	24.0	20.7	23.0
Mean	—	21.0	21.3	23.7	21.0	

(± 1.23)
S.D. = ± 4.1 (P = 0.05)
S.D. between interaction means = ± 6.9 (P = 0.05)

From these results it was concluded that a six-day fermentation using T₂ (maximum of 52° C.) represented optimum conditions. The small increase in percentage of fully-fermented beans and the smaller difference in quality score using T₂ for seven days, are unlikely to offset the danger of over-fermentation.

B. Assessment of Quality.

With the increase in the volume of small-scale cacao fermentations and the necessity for further differentiation of the products than is possible by macroscopic examination, it was essential to devise a procedure for the laboratory assessment of their quality.

Fermented beans were roasted and tasting samples prepared by procedures recommended by the B.F.M.I.R.A. laboratories in Great Britain and panels of three to six members were asked to allot points for two "quality factors," taste and aroma, of samples so prepared. The statistical design of the experiments was varied and, in addition to samples prepared by the B.F.M.I.R.A. method, assessments were made on (i) unsweetened and (ii) unroasted samples, using West African Amelonado, Upper Amazon, EI and Trinitario cacao, each sub-divided into two categories, viz., (a) flat and wrinkled beans (which were almost invariably found to have purple cotyledons) and (b) plump and fully fermented beans.

Results to date tend to show that there is no detectable difference between roasted beans of categories (a) and (b), in any of the four cacao types used.

C. *Composition of Cacao Pulp.*

A feature of small-scale fermentation of cacao is the difficulty in obtaining consistent results under similar experimental conditions. As one facet of this problem, it was decided to examine the medium of fermentation to see whether any relationship existed between the pulp sugars and the degree of fermentation. The cacao used was:—

1. West African Amelonado.
2. E1 Clonal material.
3. Upper Amazon selections T60 and T63. These are Parinari $\times$ Nanay reciprocal crosses.
4. Mixed Trinitario selections.

Four 40 lb. wet bean samples were fermented in baskets lined and covered with banana leaves. Continuous temperature records were kept using Cambridge recorders and changes in pH were followed using a glass electrode. Samples of pulp were harvested every twelve hours and the moisture, reducing sugar, and sucrose content were estimated at each harvest. Preliminary results seem to indicate that the amount of sugar available in the pulp at a given time is not critical. Replications of the initial treatment are in progress.

2. ESTIMATION OF BUTTER-FAT AND ALKALOIDS.

A. *Variation within cacao types.*

Results for West African Amelonado were discussed in detail in the 1949-50 Annual Report, but a comparison of the three cacao types used in this experiment is of interest and is summarised in the following tables of means. Butter-fat percentages are calculated on the oven-dried, unfermented nibs, and alkaloidal values are based on the weight of fat-free powder.

TABLE 16.
Table of Means.

Material.	N.	Per cent. butter-fat.	Per cent. total alkaloids.	Per cent. theo- bromine.	Per cent. caffeine.
W.A. Amelonado...	100	53.17 ($\pm$ 0.172)	2.914 ($\pm$ 0.040)	2.582 ($\pm$ 0.039)	0.332 ($\pm$ 0.005)
Upper Amazon ... (Parinari $\times$ Nanay)	50	55.45 ($\pm$ 0.244)	2.871 ($\pm$ 0.056)	2.695 ($\pm$ 0.055)	0.176 ($\pm$ 0.006)
TF2 ... (Clonal Material)	60	53.24 ($\pm$ 0.223)	2.814 ($\pm$ 0.051)	2.634 ($\pm$ 0.050)	0.180 ($\pm$ 0.006)
Mean ...		53.73 ($\pm$ 0.119)	2.871 ($\pm$ 0.027)	2.624 ($\pm$ 0.027)	0.251 ($\pm$ 0.003)

TABLE 17.
S.D. (5 per cent.).

Material.	Per cent. butter-fat.	Per cent. total alkaloids.	Per cent. theobromine.	Per cent. caffeine.
W.A.A. Vs. TF2 ...	± 0.5552 ns.	± 0.1275 ns.	± 0.1258 ns.	± 0.0149 s.
W.A.A. Vs. Upper Amazon	± 0.5889 s.	± 0.1353 ns.	± 0.1338 ns.	± 0.0158 s.
TF2 Vs. Upper Amazon	± 0.6511 s.	± 0.1495 ns.	± 0.1475 ns.	± 0.0174 ns.

TABLE 18.
Distribution of Variance Ratios.

Constituent.	Between types.	Between trees within types.
Butter-fat ...	32.59***	4.421
Total alkaloids	1.075	7.303***
Theobromine ...	1.424	7.329***
Caffeine ...	289.5***	41.63***

*** Signif. at $P = 0.001$.

A detailed analysis of the results from the Upper Amazon selections indicates that significant butter-fat and alkaloid differences exist, both apparently falling into two groups.

Butter-fat in the TF2 selections was, however, uniform and details of this interesting result are given below. Significant alkaloidal differences exist, apparently falling into three groups.

TABLE 19.
Table of Means—TF2—Clonal Material.

Tree No.	Per cent. butter-fat.	Comment.
1,285	54.25	} Uniform group.
1,208	54.10	
1,438	53.23	
1,234	52.86	
1,361	52.79	
1,209	52.24	

S.E. = ± 0.71

S.D. = ± 2.02 ($P = 0.05$)

The chief points of note from this investigation are:—

- (i) the significantly higher butter-fat content in the Upper Amazon selection (Tables 3 and 4),

- (ii) the uniformity in the butter-fat content of the TF2 Clonal material used (Table 6),
- (iii) the almost identical total alkaloid and theobromine content in all three types (Table 3); between trees, within types, however, the alkaloidal differences are highly significant (Table 4),
- (iv) the significantly higher caffeine content in West African Amelonado.

B. Seasonal Variation.

Estimations of the above constituents in this experiment continued throughout the year on (i) oven-dried, unfermented and (ii) fermented beans. The material for (i) is now harvested fortnightly, each harvest consisting of twelve pods selected at random from the Institute's Square Mile. These are divided into three groups of four, the bulked beans from each group being estimated separately. Random sampling of the Institute's bulk fermentations during the main and "light" crops provides the material for (ii).

This investigation, extending over four years, will be completed in March, 1952; publication and discussion of results will follow as soon as a statistical analysis of the figures permits.

3. CHEMISTRY OF "BLACK-POD" CACAO.

The preliminary work in this investigation, the purpose of which was described in the previous Annual Report, has been completed, and the results are summarised in the following table. The butter-fat percentage is calculated on moisture-free, shell-free cotyledons, and the alkaloids on the weight of oven-dried fat-free powder.

TABLE 20.
Table of Means.

Material.	No. of Trees.	Total per cent.				
		Butter-fat.	F.F.A.	Total Alkaloids.	Theobromine.	Caffeine.
Healthy beans	40	54.16	1.11	3.69 * $\pm$ 0.05	3.41 * $\pm$ 0.06	0.29 * $\pm$ 0.01
Diseased beans	40	54.31 $\pm$ 0.54	5.88*** $\pm$ 0.76	2.52 $\pm$ 0.05	2.30 $\pm$ 0.06	0.22 $\pm$ 0.01

* Signif. at (P = 0.05).

*** Signif. at (P = 0.001).

It is clear from these results that:—

- (i) there is no significant difference in the butter-fat content of healthy and diseased beans,
- (ii) the free fatty acid content of diseased beans is appreciably higher,
- (iii) the alkaloidal content of healthy beans is significantly higher.

When West African Amelonado pods are inoculated with pure strains of *Phytophthora palmivora* Butl., both in the laboratory and in the field, species of *Penicillium*, *Monilia*, *Aspergillus* and *Fusarium*, among others, can be isolated from the cotyledons of beans in those pods after twenty days. A study of the metabolism of the fungi which invade the cotyledons is in progress, attention being paid in particular to the reducing sugar, sucrose and protein content of the beans at varying periods after infection.

4. INCIDENCE AND DISTRIBUTION OF TANNINS IN *T. Cacao*.

Preliminary results in this experiment were recorded in the previous Annual Report. The incidence and distribution of tannins and tannin-like compounds in cacao seedlings during their first year of growth were examined by growing seedlings under uniform conditions and harvesting equal numbers, selected at random, at set periods, each harvest being divided into five groups.

The maximum extractable tannin content was ensured by estimating the tannins soluble in 40 per cent. aq. acetone and then solubilising the condensed tannins in the residue by treatment with alkali, before precipitating them with cinchonine sulphate (3). All determinations were done in duplicate on oven-dried material and corrections were used, based on the results from a comprehensive series of preliminary experiments. Results can be summarised as follows:—

- (a) Tannins and closely related substances are present in all parts of the plant.
- (b) There is a steady decrease in the extractable tannins in the whole plant during its first year of growth. In the same period there is a progressive condensation of tannins as indicated by the decrease in the 40 per cent. acetone soluble content from 57.16 per cent. of the total (uncorrected) percentage present.
- (c) The highest proportions are found in the cotyledons and, based on oven-dried (not fat-free) material, they vary in a six-week period between 11 and 30 per cent. (approx.). The tannin variation in the cotyledons is an expression of fat dispersal in the seedlings, as similar treatment on fat-free material results in tannin values varying less than 1 per cent. (33.34 per cent.), during the same period.
- (d) Flushes show little variation from 4th-12th week when leaves are yellowish-green, but increase from 11.27 per cent. (approx.) from then until the 52nd week, the latter flushes being red. Both are in marked contrast to the mature leaves which remain fairly constant between 5.5-7.5 per cent. (approx.) during the last twenty-six weeks of growth.
- (e) Roots show a steady increase from 7.12 per cent. (approx.) over the last forty weeks' growth, whilst stems fluctuate between 5.5-9.7 per cent. (approx.) over the same period.

Work is proceeding on ancillary problems which arose in the course of this investigation.

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SOIL SCIENCE.

Most of the Soil Chemist's time since his arrival has been spent in preparation for the following experiments, which will form a large part of the ensuing year's work :—

1. *The growth of T. cacao in water culture.*

The object of this investigation is to obtain visual symptom of mineral deficiencies. In the first experiment, the effect on growth of deficiencies of N, P and K, both singly and in combination, will be studied.

2. *The effect of phosphatic fertilizers upon bearing cacao.*

In this experiment, ground rock phosphate, superphosphate and double superphosphate will be compared. Two levels of each fertilizer will be used and treatments to investigate the effect of placement will also be included. The effect of these fertilizers upon soil conditions will be followed.

3. *The effect of phosphate upon the growth of cacao seedlings.*

Here, superphosphate will be applied to nursery soil immediately before planting the beans. Effects upon the growth and nutrient content of the seedlings will be followed by harvesting and analysing the plants at suitable intervals.

In addition to this work, a number of soil analyses have been carried out for the Agronomy Division.

V. BOTANICAL STUDIES.

PROGENY TRIALS.

(a) *First Progeny Trial* (Planted 1940).

The progeny of the Effiduase selection (E1) has again proved superior in yield and bean size.

General recording in the First Progeny Trial is to be discontinued and detailed observations will be restricted for the present to the six best selections. The Second Progeny Trial is of more value to the breeding programme and the labour released by this change of policy can be more usefully employed in that area.

TABLE 21.

*Yield of Ten Best Progeny in First Progeny Trial
(Main Crop Harvest, September, 1950-March, 1951).*

Selection.	Number of trees in bearing.	Total number of pods.	Mean number of pods per tree.	Mean W/W.	
				Per pod. (ozs.).	Per bearing tree (ozs.).
E1 ...	111	2,978	26.82	4.32	115.86
P3/7 ...	85	1,889	22.22	3.43	76.21
S72 ...	94	1,771	18.84	3.87	72.91
A196 ...	91	1,936	21.27	3.28	69.77
P4/9 ...	103	2,074	20.13	3.43	69.05
A220 ...	95	1,736	18.27	3.76	68.70
S84 ...	93	1,752	18.83	3.51	66.09
N38 ...	95	1,688	17.76	3.68	65.36
A187 ...	97	1,793	18.48	3.51	64.86
A20 ...	100	1,748	17.48	3.37	58.91

(b) *Second Progeny Trial* (Planted 1942).

This trial has reached a most interesting stage, the analysis of the 1950/51 main crop harvest shows that the weight of wet cocoa yielded by the selection TF1 is now superior, but not significantly greater, than E1.

TABLE 22.

*Summary of the 1950-51 Yields of the Five Best Selections—
2nd P.T.A.*

Selection.	Number of bearing trees.	Total pods harvested.	Mean number of pods per tree.	Mean wet weight per pod.
TF1 ...	53	555	10.5	4.4
E1 ...	53	504	9.5	4.6
A12 ...	45	535	11.9	3.6
U11 ...	47	428	9.1	4.3
A72 ...	38	450	11.8	3.8

NEW INTRODUCTIONS.

The introduced Upper Amazon types continue to grow vigorously. Yields for the 1950/51 main crop show a marked increase over those for 1949/50. Preliminary tests on bean quality have been carried out.

The yield of wet cocoa from the seven best types is shown in Table 23.

TABLE 23.

Yield from Main Crop Harvest, September, 1950-March, 1951.

Selection.	Average wet weight cocoa per tree in gms.
(a) <i>Introductions</i>	
Pa7 × Na32	6,142
Na32 × Pa7	5,897
Pa35 × Na32	5,448
SCA12 (♂?)	4,220
Pa37 (♂?)	4,108
IMC60 × Na34	4,078
IMC24	4,024
(b) <i>Controls</i>	
Aburi 164	1,346
Asuansi SC1	937

First Clonal Trial (Planted 1947).

An increasing number of trees is coming into bearing. The yields in these early years are not suitable for analysis owing to the uneven establishment during the initial years of this trial.

It appears that the 10 ft. × 10 ft. spacing is not suitable and the area is to be thinned on a quincunx basis.

Second Clonal Trial (Planted 1948).

Thirty-five stands came into bearing during the 1950/51 season producing 76 pods. The spacing in this trial has also proved inadequate and is to be thinned on a quincunx basis.

Capsid Resistance Trial.

This trial was surveyed and all trees showing little or no resistance to capsid damage were removed.

The remaining trees are to be thinned to a 10 ft. × 10 ft. spacing and left to further capsid attack.

CYTOLOGY AND GENETICS.

During the latter half of the year the work of the plant breeder was initiated. Preliminary cytological studies were carried out and preparations made for the pollination season.

VEGETATIVE PROPAGATION.

1. PROPAGATION BY CUTTINGS.

(a) *Experiments with rooting media.*

Following the brief note in the previous report on the comparative testing of rooting media, a randomised block experiment was laid down with four replications of the following treatments: sand, sand and fibre (oil or *Raphia* palm) in equal volumes, fibre, and wood

mould. Fifteen cuttings of clonal material of the selection SC1 were set in each bin after the usual hormone dip treatment. Watering was carried out as required rather than by routine. Temperature records were taken of the air in the bins, at the surface of the rooting media, and at four inches below the surface. pH determinations were made at the beginning of the experiment.

The cuttings were examined after 21 days in the bins and those with adequate root systems were potted. After 28 days any cuttings that had not rooted were discarded. Records were taken of the numbers of plants potted, the total number of primary roots per plant and the total primary root length: the numbers of plants successfully hardened were also recorded.

Subsequent analysis of the records showed that there was no significant difference between any of the treatments for the number of plants rooted, nor for the quantity of roots produced. There was, however, a qualitative difference in the greatly increased fibrousness of the root systems produced in those media containing organic matter. With the sand and fibre mixture there was a 10 per cent. increase in the number of plants successfully hardened.

The temperatures at the surface of the media containing organic matter were always lower than those at four inches depth, *i.e.*, at the rooting level, whilst with pure sand, the surface and rooting level temperatures were frequently below those of the air above.

The reaction of the media showed that wood mould, contrary to expectations, gave a mildly alkaline reaction; fibre, and sand and fibre mixture were neutral to slightly acid, whilst the sand was neutral.

The amount of watering required by the media containing organic matter was very much less than that required by pure sand; the amount of callus formed on the cuttings was also very much less. This implies that the conditions in these media are more favourable to rooting, as the conditions conducive to large scale callus formation are unfavourable to rooting.

The experiment was repeated with the same series of media using single leaf ("mallet") cuttings. In this case, significant increases were obtained in the number of cuttings rooted, and in the quantity of roots produced, for the sand and fibre mixture. In view of these results, this mixture has been adopted as the standard medium for routine propagation.

(b) *The useful life of rooting media.*

It is obvious that, with any rooting medium containing organic matter, the latter will slowly rot and put a period to the useful life of the medium. If the ageing of the medium is too rapid, requiring frequent replacement in the bins, then use of that medium is not economic. It is difficult to judge empirically when the medium has reached the limit of its useful life, and it was felt that the most satisfactory criterion was by its water-holding capacity in comparison with that of pure sand,

Water-holding capacity testing is being carried out at fortnightly intervals for a number of samples of the sand and fibre mixture, using the Keen-Raczkowski method. An initial comparison was made of the water-holding capacity of sand and the standard medium. The W.H.C. of the former was about 25 per cent. compared with 50 per cent. for the latter. After four months the W.H.C. of the mixture had fallen by only 1-2 per cent., and it seems certain that its useful life will be considerably longer than the six months originally estimated.

(c) *Propagation by Single-Leaf Cuttings.*

Following the trial with single-leaf cuttings, reported previously, further tests were made which confirmed the ease with which this type of material will root. Owing to the great economy of propagating material and space effected, and the ease with which even single trees can be multiplied rapidly, the use of long-stem cuttings was abandoned, and all routine propagation is now done with "mallet" cuttings.

The standard method of rooting now employs material in which the base of the fan shoot is just ripening; the leaves are fully expanded but not yet fully hardened. Normally six cuttings can be made from each shoot, but as a consequence of an experiment to be described later, the two apical leaves are discarded. The shoots are cut, each leaf having one to one-and-a-half inches of stem, and the cuttings are set 50 to a bin after treatment with the usual β Indole acetic acid and talc dip. No attempt is made to support the leaves which lie close to, or on, the surface of the sand and fibre medium.

After one month, the rooted cuttings are potted, the rest being discarded, and hardened in the usual way. After hardening they are transferred to an insectary, where, with increased heat and light, rapid bud-burst and shoot growth take place. When the plant is about 10 cms. high it is transferred to the plant shed in the normal way. This forcing method is practicable only when small numbers of cuttings are involved, but it has the merit of quickly producing uniform batches of plants for distribution.

By this method 3,300 plants have been produced for the Gold Coast Department of Agriculture in ten months; these clonal plants of the local hybrid selection E1 are required for seed production for distribution to the farmers. These plants were produced in addition to those rooted for experimental purposes, and for establishment of clones for the plant breeder. If the long type of stem cutting had been employed only about a sixth of that number of plants could have been rooted and hardened over the same period.

With the long-stem cuttings, chupon material took far longer and was far more difficult to root than fan material. With the use of mallet cuttings of chupon material, however, it was found that this type rooted quicker and more evenly than the fan material, and the subsequent outgrowth of the bud was much more rapid. In practice,

however, without special nurseries for the supply of propagating material, the small proportion of chupon in comparison with fan material limits its use. Another factor also to be taken into consideration is the ultimate habit required of the tree, as the chupon cutting behaves similarly to a seedling.

(d) *Propagation of Single-Leaf Cuttings in Wooden Frames.*

The building of a unit of the concrete propagating frames in use at the Institute is a costly and lengthy process, giving no flexibility if sudden demands are made on propagating space; moreover, they demand permanent sites. To avoid these disadvantages, tests have been carried out with low wooden, portable frames, modelled on the English cold frame. The prototype consisted of a single-light frame, but now a unit consisting of four lights, but still portable, is in use.

With this type of propagator the time taken to root the cuttings is about the same as that taken in the concrete bins, and so far, about 70 per cent. of the cuttings set have rooted. The rooting medium used is the usual sand and fibre mixture, with underlying layers of sand and broken stone for drainage. Hardening was at first effected in the normal way, but it has since been found that the rooted plants can be hardened *in situ*, the potting being done 14 days after the cuttings have rooted. This method of hardening makes these wooden frames completely self-contained units.

The Gold Coast Department of Agriculture is now trying out a number of these frames for the production of clonal plants for seed production.

2. PHYSIOLOGICAL FACTORS INVOLVED IN THE ROOTING OF SINGLE-LEAF CUTTINGS.

Water Uptake and Transpiration.

(i) *The Stomata.*

As a preliminary to any experiments on the nutrition and water uptake of cuttings during the rooting period, a number of studies were made to try and ascertain the periodicity of the opening and closing of the stomata, their dimensions and their numbers in the leaf.

Microscopical examination of strips of epidermis, obtained by Lloyd's method, showed that the stomata in cacao are extremely small, and that direct measurement of their opening and closing would be extremely difficult. Therefore, indirect measurement of the stomatal movement was tried by means of a resistance porometer. In spite of the stomata being confined to the lower surface of the leaf, and being very numerous, no variation in stomatal resistance could be detected with the apparatus, whether using negative or positive pressure. This result was confirmed by another worker independently, using similar apparatus. Using an injection technique with benzene, xylene and ethyl alcohol, at no time were the stomata found to be more than half open. When benzene was applied to the area enclosed

in the porometer cup, it was evident that in the area of the leaf immediately above the opening of the porometer cup, the stomata were closed, whilst those around the area were half open. This closure seemed to be a permanent effect as long as the apparatus was in use. Lack of time prevented this interesting effect being followed up further.

(ii) *The Uptake of Water by Single-Leaf Cuttings.*

The uptake of aqueous solutions of vital stains by freshly made, single-leaf cuttings, held in a closed chamber at 80 per cent. relative humidity, showed that even under such high humidity the uptake of water by the cut end was insufficient to balance the loss by transpiration. Withering of the petioles was evident after 24 hours, and after 36 hours the leaf was showing signs of marked water deficiency. Once wound healing had taken place no uptake of water was observed.

When the leaf tips of freshly made cuttings were cut and held under a dye solution, in a saturated atmosphere, appreciable uptake by the leaf vessels was observed after 24 hours.

It appears from the above experiments that, however carefully and quickly the cutting is made and set, there already exists a not inconsiderable moisture deficit in the leaf at the time of setting. In addition, the uptake of water is insufficient to balance transpiration unless this is reduced to an absolute minimum. Watering of the rooting medium will therefore only affect the chances of survival of the cutting indirectly, by its effect upon the atmospheric moisture in the bin, and this can be more effectively controlled by other methods. The losses by transpiration in the bins can be reduced to a minimum by frequent fine sprays on the plants, by reducing the air space in the bins as much as possible, by keeping the lower stomatal surface of the leaf as close to the moist layer of air at the surface of the medium, and by avoiding sudden rises of temperature in the bins.

The role of even the best rooting medium is very small compared with the part played by the water relations of the leaf of the cutting with the atmosphere surrounding it. As long as there is an ample supply of oxygen in it to favour rooting and a certain amount of moisture to prevent the cut end of the cutting drying, the rooting medium is of no more importance than as a means of supporting the cuttings, with a possible mechanical effect on the fibrous nature of the root system. In a number of cases, where the cutting has been accidentally pulled out of the medium and has lain on the surface, it has rooted as well as if it had been inserted in the rooting medium.

(iii) *Photosynthetic Activity in the Leaf during the Rooting Period.*

The manufacture of food materials in the leaves of single-leaf cuttings during the rooting period was investigated by comparisons, made at weekly intervals, of the dry weight of the stem with the dry weight of the leaf. The first determinations of this nature were

unsuccessful, owing to the wide variation in leaf weight. To obviate this only the three basal cuttings of each shoot were used, and these cuttings were divided into three classes on a basis of leaf area (estimated from the product of the length and breadth). Thirty cuttings of each class were set per bin, no randomization of the bins was used as previous experiments have shown that the error ascribable to inter-bin effect can be ignored. Samples of six cuttings from each class were taken at weekly intervals, and the dry weights of leaf and stem determined. Clonal parent material was used throughout.

The regression of the ratio of the stem dry weight to leaf dry weight, on time was linear and significant at 1 per cent. The decrease in the ratio with time was due to the increase in the dry weight of the stem as the leaf dry weight remained constant for the period of the experiment.

A surprising result emerged, however, in the fact that the differences in the ratios between the three leaf classes were significant at .1 per cent. There is, therefore, no relationship between leaf and stem sizes, and no significant increase in the weight of the stem of a cutting with a large leaf, relative to that of one with a small leaf, *i.e.*, the initial differences in the ratios of stem to leaf in the leaf size classes is maintained throughout the rooting period.

It appears from this experiment that considerable photosynthetic activity does take place in the leaves even under the conditions of low light intensity obtaining in the bins, and that the material manufactured is transferred to the stem of the cutting.

(iv) *The Importance of Photosynthetic Activity to the Cutting during Rooting.*

Following the conclusion from the experiment reported above, that photosynthetic activity and transfer of manufactured materials do take place during the rooting period, an attempt was made to assess the importance of these two factors to the rooting of the cutting.

To stop the flow of material manufactured in the leaf to the stem a ring of bark about three-sixteenths of an inch wide was removed from the petiole of each leaf at a point about one-quarter of an inch from the pulvinus. The xylem cylinder was scraped to remove any cambial tissue, and the wound was coated with petroleum jelly. At intervals during the rooting period, the cuttings were inspected to ensure that no callus-bridging of the wounds had taken place.

At the time the treated cuttings were set, further batches of untreated cuttings of the same clonal material were set as controls.

At the end of 28 days the cuttings were lifted, the roots measured, and then potted. At the end of 35 days from the time of insertion the shoot length of each cutting was measured. There was no difference between the treated cuttings and the controls for either the number of cuttings rooted or the quantity of roots produced. This result suggests that the cutting is dependent for food supplies

during the rooting period, upon the material actually stored in the stem at the time of taking the cutting. The conditions of light intensity in the rooting bins are of negligible importance, within a wide range, compared with the source and therefore the condition, of the parent material.

The shoot growth in the ringed cuttings at the end of the 35 days was approximately ten times that in the controls. It would appear from this that the ringing of the petioles stopped the movement of a hormone or other growth substance, which was transported in the phloem and which had the property of inhibiting partially the growth of the shoot after bud-burst. There was no difference in the time of bud-burst between treated cuttings and controls.

(v) *Rooting Potentiality Gradients in Fan Shoots.*

In the preliminary attempts to root single-leaf cuttings it was obvious that, apart from differences in rooting potentiality due to the source of the parent material, there was also a difference in cuttings from the same fan shoot. To assess these differences a randomized block experiment was laid out with six replications of the treatments, which comprised the positions of the cuttings on the original fan shoot. Clonal material of the local hybrid E1 was used, and the cuttings received the usual cultural treatment.

At the end of 28 days those cuttings which had rooted were potted after records had been taken of the number of cuttings rooted, the total number of primary roots per cutting, and the total length of primary root per cutting.

The regressions of each of the above factors on cutting position gave a linear curve, with a decreasing rooting potentiality from the base to the apex of the shoot. The differences between either of the two apical cuttings and any one of the other three cuttings, for numbers of cuttings rooted and the quantity of roots produced, were significant at 1 per cent. This effect was so marked that the two apical cuttings are now discarded for routine propagation.

It was hoped to be able to test for hormone gradients in the stem of fan shoots by a method of biological assay, but the only technique available, which did not require rigidly controlled conditions unobtainable at the Institute, was unsuccessful under West African climatic conditions. This method of assay was by the inhibition of the growth of the first true leaf of *Phaseolus vulgaris*, by application of the plant extract in solution. Although an effect was obtained it was not reproducible owing to the wide variation in the leaf size of all the varieties of bean tested.

(vi) *The Effect of Light Intensity on the Growth of Rooted Single-Leaf Cuttings.*

To test the effect of light intensity on the growth of rooted single-leaf cuttings a small scale experiment was run in an insectary with two levels of light, 50 per cent. and 20 per cent. of full daylight. Owing

to the small number of plants used, 12 per treatment, the results were intended to be qualitative only, as a guide to the handling of the plants in the plant shed. However, analysis of the results gave a significant increase in total plant dry weight for the 50 per cent. light intensity, the majority of the plants having flushed twice, whilst those under heavier shade had only flushed once.

A larger experiment was laid down in the open under shade frames which gave three levels of light intensity: 50 per cent. diffused light, 75 per cent. diffused light, and 50 per cent. dappled light. Fifty plants were given to each treatment, but owing to shortage of material only one replication was possible. Records were made of the air temperature, the relative humidity and the evaporating power of the air. Samples of four plants from each treatment were taken at fortnightly intervals, total plant dry weight and total leaf area being recorded.

It was obvious from the time that bud-burst started that the growth of this type of plant was very uneven, and the wide variation persisted for the three treatments for the period of the experiment. No difference was shown between treatments for either leaf area or dry weight per plant.

The data were also used to investigate the net assimilation rate of the cuttings under each of the three treatments. The linear component of the regression of plant dry weight on total leaf area per plant was highly significant, as were those for total leaf area on time and dry weight on time. From these the total dry weights were corrected to total leaf area and time. Using the corrected values the net assimilation rates were calculated for each of the treatments for ten fortnightly periods.

TABLE 24.
Net Assimilation Rates under Different Light Intensities.
(gm. dry matter per square decimetre.)

Period.	50% Diffuse.	75% Diffuse.	50% Dappled.
1	1.139	1.210	0.682
2	1.094	1.061	1.361
3	0.989	0.815	0.904
4	0.765	0.606	0.877
5	0.373	0.453	0.864
6	0.581	0.730	0.846
7	0.464	0.786	0.825
8	0.603	0.896	0.890
9	0.759	0.977	0.702
10	1.105	1.037	0.762
Mean	0.7872 (± 0.1234)	0.8571	0.7359

The differences between the means for the three treatments are not significant. The fall in the leaf efficiency, coincides, as would be expected, with the hardening of the flush, and then begins to rise again as the new flush is produced. In spite of its comparatively long life, the maximum efficiency of the leaf has been attained before the flush has fully hardened.

When the net assimilation rates for the three treatments are calculated for weekly periods, the values fall within the ranges quoted for a wide range of other species under widely differing environmental conditions (Heath and Gregory, 1938), but are sharply at variance with those obtained by Goodall (1949) for cacao seedlings.

It is obvious from the data of this experiment that with cacao cuttings selection of the plants for the experiment on a basis of a common time of insertion of the cuttings leads to a very high degree of experimental error. Selection on a basis of morphological age would tend to remove most of the error ascribable to internal factors which affect the rate of growth and development of the cutting, irrespective of the experimental conditions to which the plant is exposed.

3. INTERSPECIFIC GRAFTS IN THE GENUS *THEOBROMA*.

As reported in the previous Annual Report, a fairly high degree of success was obtained with grafting the tips of young flush shoots on one-month-old seedlings. The stock is decapitated and then split down to cotyledon level; the end of the scion is cut to a wedge, fitted in the stock and tied, the whole being held under a bell jar. Union normally takes place in about 10 days. This technique was later used to graft scions of other species of *Theobroma* on to cacao. Of six species so tested, one successful union was obtained with *Theobroma bicolor* on a Trinitario type seedling stock.

Using scions of the same species as were grafted above, a number of bottle approach grafts were made on cacao stocks. In this type of graft a detached scion is used, the end of which is held in a tube of water plunged in the pot containing the stock. With this method a successful union was obtained with *Theobroma microcarpum* on a cacao seedling stock. The scion grew away quickly, and flowered precociously three months after the graft had been made.

These methods of grafting are too laborious, and the chance of success is too low for them to be of any practical value. They are of interest, however, as being the first recorded grafts between species, as far as is known, in the genus *Theobroma*.

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VI. MYCOLOGY.

The mycological work at the Institute during the year 1950-51 has been confined to two main problems: (1) Comprehensive Pod Classification Investigation, and (2) Pod Disease Control. The experiment on the control of diseases by fungicide sprays and weekly harvesting has given results which are in the main comparable with the results obtained during the year 1949-50. The Comprehensive Pod Classification Investigation experiment has shown the relationship between high rainfall and the high incidence of initial pod infection by *Phytophthora palmivora* Butl., and many other factors of interest.

POD DISEASE CONTROL.

The experiment was a continuation of the one set up three years ago to study the effect of various treatments on the incidence of pod diseases (Ann. Rep., W.A.C.R.I., 1948-49). During the year 1950-51, however, slight changes have been made in recording the incidence of black pod (caused by *Phytophthora palmivora* Butl.) in that a distinction was made between the primary or initial infection of the cacao pod and the infestation which originated from an infected tree cushion. Also D.D.T. at 0.1 per cent. was substituted for nicotine sulphate in the spraying programme. As in previous years, the records showed that although the incidence of pod diseases was reduced, especially black pod disease, under fungicide spraying, no treatment influenced the mean weight of wet beans per pod. This latter figure is of the greater economic importance.

The incidence of black pod during 1950-51 was lower than in the 1949-50 season, the mean percentage of pods infected with *Ph. palmivora* in the control plots was 13.94 compared with 14.6 per cent. for 1949-50 and 12.5 per cent. for 1948-49 seasons. The explanation for this reduction may be found in the comparatively low rainfall during the main crop harvest and the topographical conditions of the experimental area.

The tabulated results were obtained from harvests covering the total crop for the season. However, the analysis of records presented here deal only with the incidence of black pod since the incidence of other diseases are only of minor significance and are dependent upon numerous factors causing mechanical damage to pods.

It was recorded that the total harvests from the Control and Bordeaux-treated plots was significantly lower than on the plots which had other treatments. The following reasons are presented for this condition. On an inspection of the Control plots it was observed that the number of cankered cushions on the trees was greatly in excess of those found on other plots and these cankered cushions were non-productive. In the Bordeaux-treated plots the loss of crop appeared to be due to the poor set owing to the apparent burning of the blossoms by the continual weekly spraying of the Bordeaux mixture, a condition

that did not arise with the Perenox treatment which is also a copper fungicide.

The mean percentage of pods primarily infected with *Ph. palmivora* in each treatment is shown in the table below. The infections from cushions are not presented since it is reasonable to assume that treatment with fungicides would have no effect on the infection which arose from this source.

TABLE 25.

<i>Treatment.</i>	<i>Mean % of Black Pod.</i>
Control	13.94
Weekly harvesting	12.25
D.D.T.	10.78
Spraying with Perenox	6.80
Spraying with Bordeaux	8.13

The following table gives the mean weight of good wet beans per pod :—

TABLE 26.

<i>Treatment.</i>	<i>Mean weight of good wet beans in ounces.</i>
Weekly harvesting	3.626
Spraying with Perenox	3.496
Spraying with Bordeaux	3.557
D.D.T.	3.507
Control	3.600

It is shown in the first table that a considerable control of primary *Ph. palmivora* infections was obtained by spraying with Perenox and Bordeaux, infection following either treatment being significantly less than in the case of the other three treatments.

Although there was a slight reduction in the incidence of black pod on the weekly harvested plots over the Control plots, there was no significant difference between these two treatments when ($P = 0.05$) = 2.399.

It will also be noted that the weekly harvesting again gave the greatest mean weight of good wet beans but not significantly different from the other treatments at the 5 per cent. level.

COMPREHENSIVE POD CLASSIFICATION INVESTIGATION.

The object and lay out of this experiment were reported in the Annual Report W.A.C.R.I., 1949-50. The investigation has been conducted as then laid out with the exception that the black pod infection (caused by *Ph. palmivora* Butl.) has been recorded as primary or cushion infection. This modification was undertaken since it was apparent that the majority of black pods which become infected from the cushions appear at the beginning of the main crop season, whilst the incidence of primary infections followed the periods of heavy rainfall.

An attempt was made to correlate temperature, humidity and rainfall with the incidence of primary infection of *Ph. palmivora* and for this purpose, hygrographs and thermographs were set up in three of the experimental plots. These plots were chosen to give varying conditions of shade ventilation, soil moisture content and surrounding openness. The humidity followed a fairly constant course on all three plots ranging between 80 per cent. and 90 per cent. relative humidity during the crop season. However, the relative humidity records on plot B22 were influenced by the closed cacao canopy and the heavy top shade. There is a high peak of cushion infection at the beginning of the main crop season, this no doubt being due to the infected cushions producing pods following the heavy June rains. The incidence of cushion infection and primary infection follow much the same trend throughout the season with the highest peak in October, which was the month of heaviest rainfall. It is quite clear that humidity in itself has practically no bearing on the incidence of black pod but that it is closely related to the fluctuations in rainfall coupled with the ventilation through the cacao canopy. In plot B22 the incidence of primary infection of black pod is significantly related to the rainfall when $P < 0.01 > 0.001$.

The following table gives a summary of the recordings for the months of June to January inclusive as monthly mean percentages.

TABLE 27.

	Month.							
	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
Total number of Pods ...	452	1139	566	1688	2966	2591	2513	949
Percentage from								
Branch	72.8	52.5	78.1	56.7	63.3	79.5	92.6	99.5
Upper trunk	21.6	26.1	5.3	20.0	21.6	17.6	7.2	0.5
Lower trunk	5.6	21.4	16.6	23.3	14.8	2.9	0.2	0.0
Percentage								
Mature	95.6	95.2	81.4	99.1	98.9	98.7	100.0	99.1
Immature	4.4	4.8	18.6	0.9	1.1	1.3	0.0	0.9
Percentage discarded ...	15.9	10.3	26.9	6.2	10.6	7.3	7.7	14.2
Percentage damaged by								
Black pod (cushion) ...	5.5	6.9	20.3	6.4	7.2	5.6	5.1	3.4
Black pod (initial) ...	4.4	4.4	9.9	6.1	9.2	6.0	3.6	1.3
Black pod (total inf.) ...	9.9	11.3	30.2	12.5	16.4	11.6	8.7	4.7
Mealy pod	0.0	0.2	0.5	1.5	2.6	2.1	0.6	0.04
Brown pod	6.2	1.1	1.9	1.0	0.5	0.08	1.9	2.2
Warty pod	8.8	14.1	16.4	15.8	8.4	5.9	4.1	2.3
Fusarium	1.3	1.2	1.9	3.1	0.7	0.8	0.6	0.6
Helopeltis	75.4	78.5	62.7	48.6	40.3	47.6	54.3	53.8
Other capsids	7.7	7.9	8.1	6.6	9.4	9.1	6.5	5.3
Scale insects	11.7	5.5	1.8	1.9	1.1	1.4	2.9	2.2
Rodent	11.5	8.2	8.5	3.5	4.3	2.1	1.7	4.3
Borers	34.3	25.7	19.3	12.1	11.2	11.5	17.6	11.0
Mechanical	3.5	2.9	2.5	1.1	0.9	1.4	0.4	1.5
Unidentified	0.0	0.4	0.9	0.06	0.0	0.15	0.8	0.3
Weight of wet beans (lbs.)	91.5	265.2	103.8	362.9	569.4	467.3	446.5	153.9

As in the previous crop season no class of damage was as important as the black pod disease. Again the majority of the pods were damaged by *Helopeltis* sp., but this damage was only superficial and did not affect the beans. The number of pods discarded was related to the number damaged by either rodents, borers or mechanical means. In all cases these pods were infected by either *Botryodiplodia theobromae* Pat. or *Trachysphaera fructigena* Tab. & Bunt.

The proportion of immature pods again rose in August; this being due to the increase in black pod infection arising from the *Ph. palmivora* Butl. infected cushions and immature pods were only harvested if diseased. The beans are invariably useless and are discarded.

As in the 1949-50 season the percentage of pods discarded rose at the end of the main crop season. This being due to the increase in rodent and borer damage.

It is also interesting to note that the majority of pods infected with primary infection of the black pod disease were harvested from the lower trunk, whilst those infected from the cushion came from both the upper and lower trunk. Only a small portion of the infections appeared on the branches.

VII. MEALYBUG STUDIES.

BIOLOGICAL CONTROL OF MEALYBUGS.

A. Introduction of exotic parasites.

1. The rearing of *Anagyrus* sp. nr. *kivuensis* Compere, introduced from Kenya, was discontinued as the culture became seriously contaminated with *A. pullus* and the equipment was required for work on other introduced parasites.

2. The following species, received from the Commonwealth Bureau of Biological Control's laboratory in California, have been tested to see if they would develop in the commoner Gold Coast mealybugs:—

- (a) *Pseudaphycus angelicus* Howard has been reared on *Pseudococcus njalensis* Laing, *P. brevipes* Ckll., *P. longispinus* Targ., *Phenacoccus madeiriensis* and *Ferrisia virgata* (Ckll.). It has been seen to oviposit in *P. citri* but no adults have emerged from this host.
- (b) *Pauridia peregrina* Timberlake has been reared on *P. njalensis* and *P. citri*.
- (c) *Chrysoplatycerus splendens* Howard has been reared *P. brevipes* only in small numbers.
- (d) *Tetracnemus pretiosus* Timberlake failed to reproduce on any indigenous mealybug and attempted oviposition only in *P. virgata*. Shipments of this species have been discontinued.
- (e) *Coccophagus gurneyi* Compere was introduced in small numbers and oviposited in *P. njalensis*, *P. citri* and *P. brevipes*—the only species tested—but no adults emerged.

Shipments of this species were discontinued as a supply of mealybugs attacked by another parasite species on which males of *C. gurneyi* could be reared could not be guaranteed. (Females of this species develop as primary parasites of Coccidae, while the males are hyperparasitic in habit.)

- (f) The following species, still under test, have not reproduced in the Gold Coast to date: *Allotropa* sp. nov., *Anharopus sydneyensis* Timberlake, *Acerophagus pallidus* Timberlake, *Tetracnemus peregrinus* Compere.

A single shipment of adults of *Acerophagus notativentris* Girault was sent from California, but all died in transit. All other species have been shipped by air as prepupae or pupae in mummified mealybugs and most have arrived in satisfactory condition. Of the few which failed to give a reasonable number of emergents after arrival at Tafo, the majority were shipments of *Pauridia peregrina* from several of which no adults emerged. Other shipments of this species have been more or less satisfactory, and while most of the failures occurred in cases where more than eight days were passed during transit, delays in transit alone do not account for the high mortality.

B. Releases and recoveries of natural enemies.

No specimens of the parasite *Leptomastix dactylopii* Howard or of the coccinellid predators *Chilocorus angolensis*, *Exochomus flavipes*, *Scymnus bineavatus*, *S. quadrivittatus* and *Nephus* sp. have been recovered since the liberation of these species in 1949.

38,000 adults of *Pseudaphycus angelicus* have been liberated at three stations in the Eastern Province since September, 1950. A single adult of this species has since been reared from a specimen of *P. njalensis* collected from cacao at one of these stations.

2,500 adults of *Pauridia peregrina* were liberated during the last five weeks of the year under review.

Rearing of mealybugs for parasite breeding.

Suitable potatoes for the mass rearing of mealybugs on potato sprouts have been procurable only in very limited quantities and the search for further suitable host plants has continued. Cacao continues to be the most satisfactory host for *P. njalensis* and small colonies suitable for testing of introduced parasites can readily be obtained if the mealybugs are ant attended. Larger colonies suitable for the rearing of the large numbers of parasites required for liberation in the field do not readily develop. *Solanum verbascifolium* seedlings are most suitable for rearing of *P. citri*. Several good colonies have developed during the few weeks for which this plant has been used and a further supply of seedlings has been raised on which it is hoped to rear *P. citri* in large numbers.

Other plants tried include banana, pine-apple, Jerusalem artichoke, sugar-cane, *Canna*, *Costus afer*, *Cola cordifolia*, cocoyam,

Chinese yam, groundnut seedlings, *Acalypha*, *Napoleona*, *Cereas*, *Portulaca*, and three species of *Euphorbia*, but none proved as satisfactory as those previously mentioned.

Indigenous parasites and predators.

937 natural enemies of *P. njalensis* have been reared from 16,000 specimens of this mealybug collected in the Gold Coast, and 124 enemies of *P. citri*. Small numbers of parasites have also been reared from the following less common mealybugs:—

P. celtis Strickland, *P. longispinus* Targ., *P. bukobensis* Laing, *P. brevipes* Ckll., *Phenacoccus ?madeiriensis*, *Paraputo ritchei* Laing and *Ferrisia virgata* (Ckll.).

CHEMICAL CONTROL OF MEALYBUGS.

Since the Potter Tower received by the Institute had not become fully operative, it was decided to initiate a small field trial to test the effect of various insecticides on mealybugs and/or attendant ants.

Small trees carrying carton tents and capable of being sprayed with a 4 ft. lance on a knapsack sprayer were used.

Since the carton tents cannot be disturbed before treatment, the number present on each tree was counted. Four days after treatment every tent on each tree was opened and the presence or absence of mealybugs noted, and if present, whether alive or dead. The presence or absence of attendant ants was also noted. Six trees were used for each treatment and the total number of carton tents carried varied between 45 and 115 per treatment.

Insecticides were used as smokes, dusts and sprays in the following formulations:—

D.D.T.	...	...	Smoke.
"	...	...	5% dust.
"	...	...	1% aqueous emulsion.
B.H.C.	...	...	Smoke.
"	...	...	Dust containing 0.65% gamma isomer.
"	...	...	Aqueous emulsion containing 0.03% gamma isomer.
Nicotine	...	...	2% dust.
"	...	...	0.1% solution (nicotine sulphate).
Parathion	...	...	0.015% aqueous emulsion.

Smoking was carried out by putting the generator in a simple holder and moving so that all foliage was thoroughly smoked.

Dusting was done by means of a hand-operated machine. *Spraying* was carried out by a knapsack sprayer.

TABLE 28.—*Results.*

1.

Treatment.	Mealybugs.		Ants present. %
	Healthy. %	Dead or absent. %	
D.D.T. smoke ...	79	21	100
„ dust ...	54	46	17
„ emulsion ...	66	34	0
B.H.C. smoke ...	91	9	100
„ dust ...	60	40	67
„ emulsion ...	57	43	100
Nicotine dust ...	41	59	100
„ solution ...	12	88	100
Parathion emulsion ...	24	76	100
Controls ...	97	3	100

% = Percentage number of tents.

It will be noted that the percentage of empty carton tents in the Controls was only 3 per cent. whereas the figure for empty or those containing dead mealybugs for Nicotine solution was 88 per cent. It has been confirmed in the Institute that, where mealybugs are killed, the bodies are removed or eaten by ants and it has been assumed that this has taken place in the present trial. In fact, few tents containing dead mealybugs have been found.

It is apparent from these figures that smokes are not effective against mealybugs in carton tents.

With dusts and D.D.T. and B.H.C. sprays the kill obtained is too low for effective control.

Parathion and Nicotine, however, have given a kill of the order of 76 per cent. and 88 per cent. respectively. Considering the protection afforded by tents it is assumed that much of this kill has been achieved by fumigant action.

In view of the results obtained with Parathion and Nicotine, further experiments were performed using several concentrations.

Formulations used were :—

Parathion	...	...	0.015% aqueous emulsion.
„	...	...	0.03% „ „
Nicotine	...	...	0.1% solution (nicotine sulphate).
„	...	...	0.2% „ („ „).
* Aldrin	...	...	0.2% aqueous emulsion.
** Dieldrin	...	...	0.2% „ „
Chlordane	...	...	2.0% „ „

* 1,2,3,4,10,10—hexachloro—1,4,4a,5,8,8a—hexahydro—1,4,5,8—dimethanonaphthalene.

** 1,2,3,4,10,10—hexachloro—6,7—epoxy—1,4,4a,5,6,7,8,8a—octahydro—1,4,5,8—dimethanonaphthalene.

TABLE 29.

2.

Treatment.	Mealybugs.		Ants present. %
	Healthy. %	Dead or absent. %	
0.1 per cent. Nicotine solution ...	4	96	22
0.2 per cent. " " ...	1	99	11
0.015 per cent. Parathion emulsion	18	82	2
0.03 per cent. " " "	20	80	1
0.2 per cent. Aldrin emulsion ...	16	84	0
0.2 per cent. Dieldrin emulsion ...	41	59	0
2.0 per cent. Chlordane emulsion	50	50	0
Controls	86	14	100

% = Percentage number of tents.

It will be noted that Nicotine solution at both 0.1 per cent. and 0.2 per cent. gave excellent control.

Parathion at 0.015 per cent. yielded a good kill but doubling the concentration gave no improvement.

Aldrin was comparable to Parathion but Dieldrin and Chlordane gave a low kill.

It is considered of great interest that these four materials have cleared the trees of ants. The latter were all *Crematogaster* species. Further work is being done on this problem.

It would appear from these repeated figures that Nicotine solution can give appreciable control even of mealybugs protected by carton tents. It is, of course, an accepted material for control of mealybugs where carton tents do not occur.

It must be emphasised, however, that the treatments in these trials were made under conditions not to be found on cacao farms.

VIII. ARBORICIDES.

It was recommended in the Report of the Technical Mission to the Gold Coast (1949) that arboricides should be used to kill (1) diseased cacao, either *in situ* or by treating stumps after felling and (2) forest trees known to be alternative hosts of the virus or vector of swollen shoot disease.

Accordingly work has been carried out using almost all the chemicals mentioned in the Report.

(1) CACAO.

Materials have been applied to mature trees both by pouring into a frill girdle cut round the tree and by pouring over the cut surface

of the stump after felling. Two trees have been used for each treatment.

Frill Girdling.

Preliminary experiments indicated that the frill must be cut as close to the base of the trunk as possible. If the frill is made some distance up the trunk the tree may be killed above the frill, but a large number of shoots is frequently thrown out immediately below it. Frilling was done by cutlass and consisted of simple cuts round the circumference of the tree spaced so that each cut overlapped the next thus ensuring that the cambium was completely severed. The arboricidal material was then immediately poured or placed in the frill.

A series of experiments was performed employing a double frill. The normal frill was cut at the base of the trunk and a second cut about one foot above it.

Stump treatment.

The trees were felled by cutlass leaving stumps not more than four inches in height. These were then slashed three times across the cut surface in one direction, and three times at right angles to the first direction. Such cuts materially assist penetration. The arboricidal material was then immediately poured or placed on the cut surface.

Materials Used.

Sodium arsenite, aqueous solution, 2.5 per cent.—50 per cent.



1. Sodium arsenite, starch solution, 5 per cent.—20 per cent. As_2O_3 .
Ammonium sulphamate (Ammate), aqueous solution, 2.5 per cent.—50 per cent.
 2. Ammonium sulphamate (Ammate), dry salt, 2.5 grm—25 grm.
n-butyl ester of 2,4-D, 5 per cent. in T.W.O.
n-butyl ester of 2,4,5-T, 5 per cent. in T.W.O.
50/50 mixture of *n*-butyl esters, 5 per cent. in T.W.O.
iso-propyl ester of 2,4-D, 5 per cent. in T.W.O.
iso-propyl ester of 2,4,5-T, 5 per cent. in T.W.O.
50/50 mixture of iso-propyl esters, 5 per cent. in T.W.O.
50/50 mixture of iso-propyl ester of 2,4-D, and *n*-butyl ester of 2,4,5-T, 5 per cent. in T.W.O.
 3. High Aromatic Oil.
 4. Atlacide 10 per cent. and 20 per cent. aqueous (only available for double frill experiments).
 5. "Weedicide" (only available for double frill experiments).
1. Formulated with gelatinised starch to yield a viscous solution which tends to be retained in the frill.
 2. T.W.O. Technical White Oil. Shell Petroleum Co. product.
 3. Non-phytotoxic Distillate containing 30 per cent. aromatic compounds. Product of Anglo-American Oil Co. Ltd.
 4. Plant Protection Ltd. product containing 60 per cent. sodium chlorate with a fire suppressant.
 5. Plant Protection Ltd. product, containing sodium arsenite, 35 per cent. As_2O_3 w/w.

Preliminary trials had shown the following materials to have little or no toxic effect:—

Dinitro-sec-butyl phenol (D.N.B.P.).

Dinitro-o-cresol (D.N.O.C.).

Pentachlorophenol.

Potassium ethyl xanthate.

Method of Assessment.

No tree was considered dead until it could be pushed over with a moderate effort and the basal fracture examined.

Similarly a stump was deemed to be dead when it could be broken with ease into fragments.

TABLE 30.
Results of Aboricide Treatment.
(Complete kill indicated by +.)

Material.		Single frill.	Double frill.	Stump treatment.
Sodium arsenite, aqueous solution	2.5%	—	+	—
" " " "	5%	—	+	+
" " " "	10%	+	+	+
" " " "	25%	+	+	+
" " " "	50%	+	+	+
Sodium arsenite, starch solution	5%	+	+	+
" " " "	10%	+	+	+
" " " "	20%	+	+	+
Ammate, aqueous solution	2.5%	—	—	—
" " " "	5%	—	—	+
" " " "	10%	—	—	+
" " " "	25%	—	—	+
" " " "	50%	+	+	+
Ammate, dry salt	2.5 grm.	—	—	—
" " " "	5 grm.	—	—	—
" " " "	10 grm.	—	—	—
" " " "	25 grm.	—	+	—
High Aromatic Oil	...	+	+	+
Atlacide, aqueous solution	... 10%	Not used	+	Not used
Atlacide, aqueous solution	... 20%	Not used	+	Not used
" Weedicide "	...	Not used	+	Not used
n-butyl ester 2,4-D	... 5%	+	Not used	+
n-butyl ester 2,4,5-T	... 5%	+	Not used	+
50/50 mixture n-butyl esters	... 5%	+	Not used	+
Iso-propyl ester, 2,4-D	... 5%	—	Not used	+
Iso-propyl ester 2,4,5-T	... 5%	+	Not used	+
50/50 mixture iso-propyl esters	... 5%	+	Not used	+
50/50 mixture iso-propyl 2,4-D and n-butyl 2,4,5-T	... 5%	+	Not used	+

Summary.

It would appear from the above results that double frill girdling and stump treatment are both slightly more effective with some materials than single frill girdling. Most noticeable is the success of stump treatment using aqueous ammate solution.

The slightly improved performance of sodium arsenite in starch formulation is not considered sufficient to warrant its use, especially as its preparation is somewhat complicated.

The results obtained from the use of growth regulators are in keeping with the view that the esters of 2,4,5-T and mixtures of them with esters of 2,4-D are more effective on woody growth than those of 2,4-D alone. It is worthy of note that the *n*-butyl esters appear to be somewhat quicker-working than the others.

(2) FOREST TREES.

The forest trees employed in the experiments were *Ceiba pentandra* and *Cola cordifolia*. Both species can grow to huge dimensions, *Ceiba* reaching 200 feet high and *Cola* 120 feet.

Felling such trees is a major operation and the felled tree can cause widespread damage to the cacao beneath. Where, however, they are killed standing they disintegrate slowly and the falling pieces cause relatively little damage. This has been confirmed in practice.

Application of any poison is complicated by the presence of buttresses on both species. These buttresses may extend thirty feet up the trunk of a *Ceiba*. Thus, in order to reach the main trunk of any such trees, it would be necessary to employ ladders and staging.

For these experiments it was decided to treat medium sized trees before proceeding to the very large ones. Trees of 2 to 3 feet diameter and 60 to 100 feet in height are regarded as being of medium size; by ordinary standards they are, of course, quite large trees.

Method of Application.

It was decided in the first place to use as simple an application technique as possible. Accordingly, the trees were ring-barked 3 to 4 inches wide at breast height, in and out of the buttresses, by means of hatchets and chisels. In this way, two men can ring a large tree in thirty minutes. Immediately after ringing, the poison was poured or placed in the ring.

In later experiments, 1-inch diameter holes were drilled in the ring to a depth of about 6 inches by means of a carpenter's bit and brace. Whenever possible, holes were drilled so that one occurred on the edge of each buttress and one in the joint between each pair of buttresses. Two trees were used for each treatment.

Materials Used.

Sodium arsenite, aqueous solution, 35 per cent. and 50 per cent.

As_2O_3 .

1. Sodium arsenite, starch solution, 5-20 per cent. As_2O_3 .
2. "Weedicide."
Ammonium sulphamate (Ammate), dry salt.
3. High Aromatic Oil.
4. "Atlacide."
5. "Santophen 20," 5-10 per cent. in 6 T.W.O.
6. *n*-butyl esters of 2,4-D and 2,4,5-T and mixtures thereof in T.W.O.
Iso-propyl esters of 2,4-D and 2,4,5-T and mixtures thereof in T.W.O.
7. YF 2619, 5 per cent. ester in T.W.O.
8. YF 2631, 5 per cent. ester in T.W.O.
9. YF 2717, 5 per cent. ester in T.W.O.

Results.

Before considering toxic effects on these trees it should be pointed out that they appear to contain very large reserves, as witness the fact that a felled tree may continue throwing out shoots twelve months after felling.

With the exception of the first arsenite treatments (5, 10 and 20 per cent. As_2O_3) most treatments have run for between two and eight months. It is considered, therefore, that a further interval should elapse before drawing conclusions concerning toxicity.

AMMATE, HIGH AROMATIC OIL, "ATLACIDE" AND "SANTOPHEN 20."

These materials may be said, so far, to have had no effect upon trees of either species.

SODIUM ARSENITE.

Ceiba Pentandra.—With starch incorporated, 20 per cent. As_2O_3 has given a kill. "Weedicide" (35 per cent. As_2O_3) has given a kill in a shorter time. This time has again been reduced by drilling holes in the tree.

1. Formulated with gelatinised starch to yield a viscous solution which tends to be retained in the ring.
2. Plant Protection Ltd., product containing sodium arsenite, 35 per cent. As_2O_3 w/w.
3. Non-phytotoxic Distillate containing 30 per cent. aromatic compounds. Product of Anglo-American Oil Co. Ltd.
4. Plant Protection Ltd., product containing 60 per cent. sodium chlorate with a fire suppressant.
5. Monsanto Chemicals Ltd., product. Emulsion concentrate containing 20 per cent. pentachlor phenol.
6. Technical White Oil. Shell Petroleum Co., product.
7. Plant Protection Ltd., product. Emulsion concentrate containing 25 per cent. each of *n*-butyl esters of 2,4-D and 2,4,5-T.
8. Plant Protection Ltd., product. Emulsion concentrate containing 33 per cent. *n*-butyl ester of 2,4-D and 17 per cent. *n*-butyl ester of 2,4,5-T.
9. Plant Protection Ltd., product. Emulsion concentrate containing 33½ per cent. *n*-butyl ester of 2,4,5-T.

Cola cordifolia.—Results are not as definite as in the case of *Cerba*.

It would appear that those trees containing drilled holes are likely to die although sufficient time has not yet elapsed to say so with certainty.

ESTERS OF 2,4-D AND 2,4,5-T.

While no trees of either species have yet died, these materials and mixtures of them have had a profound effect. The bark and cambium have split and become a mass of sodden and decomposed tissue. This effect obtains both above and below the ring. It appears that the esters of 2,4,5-T and the mixed esters have a somewhat greater effect than those of 2,4-D.

It is difficult to visualise these trees surviving such severe damage.

Summary.

It is pointed out that these are preliminary experiments only. Materials had to be applied as they were received and consequently it was not possible to attempt any correlation of toxic action with seasonal condition of the tree. Translocation in general appears to take place more readily downward than upward. Further, where buttresses are concerned, translocation takes place readily down the edge of each buttress to ground level but not down the buttress panels.

IX. AGRONOMY.

SUB-STATIONS.

Rainfall during the early half of the year was adequate and growth of the cacao was satisfactory on all plots.

A spell of dry weather in August caused heavy defoliation on the Akwadum plot, but the other stations continued to make good progress until February when the drought effect was particularly severe on all sub-stations except Adonkwanta.

At Akwadum a large number of young trees, growing on the sandy soils, were killed by complete desiccation. Weeding and shade control were confined to the wet season on all farms.

Akwadum.

As mentioned above this farm suffered severely during the December-February dry period and 2,240 young trees failed to recover from the effects, whilst all the other trees had a severe set-back and made a very slow recovery after complete defoliation.

Capsid control was effected by the use of D.D.T. emulsion applied by mechanical means, the hand-painting technique being no longer possible due to the size of the trees.

The incidence of swollen shoot disease was confined to the perimeter of the farm, 14 trees being infected, mostly in the early part of the year, prior to the removal of all infected trees in the Resistance Trial Area which is situated on the northern and western borders of the main experimental area.

2,630 pods were harvested from the farm during the year.

Nankese.

The cacao on this farm continued to make highly satisfactory progress and has formed a complete canopy on the better soils.

The progress of the cacao on those areas where establishment had been difficult in the early years has improved with the attainment of good shade conditions.

It is noteworthy that whilst the growth of Amazon seedlings have been poor, they have survived the second dry season under conditions where Amelonado seedlings have again died out.

No swollen shoot disease occurred during the year under review.

Capsid damage was negligible. 825 pods were harvested.

Kukua.

Heavy defoliation of the cacao occurred on the shallow hilltop soils but good March rains induced a good new flush, only 5 per cent. of the seedlings failing to make a satisfactory recovery.

Cacao in the valleys and on the valley slopes has continued to make excellent progress and 4,365 pods were harvested, mainly from these areas.

Vacancies have been filled as climatic conditions permitted and in the more forward areas the cacao has been thinned to one tree per stand.

Capsid damage was negligible. Ten seedlings were discovered with virus symptoms during the year, nine of them being in Plot A, and associated with other diseased seedlings which are apparently infected with an extremely benign strain, as the majority, although first recorded in 1948, are still growing well.

Adonkwanta.

The effect of the December-February dry spell was less severe on this sub-station than on those nearer the coast.

Shade control included thinning the rain tree shade by ring-barking a proportion of the main branches and removal of some of the less desirable forest tree seedlings.

There was a limited amount of damage by adult capsids to the upper storey of the cacao in Plot B. But the situation was brought under control by hand painting with D.D.T. emulsion, following the failure of dusting with D.D.T. in talc to effect control.

Growth of the seedling cacao was slower than on the other sub-stations and only 186 pods were harvested during the year.

Seven seedlings were removed after swollen shoot symptoms had appeared; all were on the perimeter of the untreated plot.

Koransang.

Swollen shoot disease continued to take a toll of the mature trees on the farm, but despite this the number of diseased seedlings was astonishingly low.

Losses due to the disease amounted to 209 mature trees, six coppiced trees and 23 seedlings. Growth of seedling cacao was good except on the areas of shallow soils overlying rock.

Capsid damage was confined to the upper growth of some of the more advanced seedlings.

2,189 pods were harvested mainly from the 1945 planted cacao.

TAFO STATION.

A. CACAO CROP.

1. *Old Station.*

The minor crop harvest began in June and was completed by the third week of August, the major crop following two weeks later and lasting until February.

The incidence of black pod disease was much lower than in the previous year, the rainfall for June, July and August being considerably below the 13-year mean.

The crop as a whole was slightly larger in terms of number of pods harvested (.3 per cent.). Due to the higher drying percentage and lower loss from black pod, however, the final yield per acre of dry cacao was 4.54 per cent. higher than that of the previous season.

A comparison between the current year's light and main crops and those of last season is shown in Tables 31 and 32 the delivery of the whole crop in Tables 33a and 33b and the comparative figures for the present season, the previous season and the 13-year mean in Table 34, all figures being in respect of the 63.6875 acres of the Uniformity Trial Area.

TABLE 31.

Year.	Pods harvested.	Per cent. pods discarded.	Wet weight in lbs.	Per cent. dry to wet weight.	Pods per lb. dry.
1949 ...	86,553	20.8	16,297.2	34.8	11.1
1950 ...	44,924	5.6	9,577.3	37.3	10.9

TABLE 32.

Year.	Pods harvested.	Per cent. pods discarded.	Wet weight in lbs.	Per cent. dry to wet weight.	Pods per lb. dry.
1949 ...	364,535	4.2	77,660.0	39.27	11.1
1950 ...	407,753	3.2	78,222.2	41.74	11.6
per cent. + or — over last year ...	11.86	1.0	0.72	2.47	

TABLE 33a.
(*Light Crop.*)

Date of picking.	Total pods harvested.	Per cent. pods discarded.	Wet weight in lbs. beans.	Per cent. dry/wet.	Pods per lb. dry.	Pods for seed.
June 5-7	2,270	5.9	359.1	40.13	11.7	455
„ 16-17	2,710	3.4	363.7	40.80	10.9	1,006
„ 26-30	8,090	6.2	1,614.6	34.29	12.4	732
July 10-17	13,863	3.1	3,355.4	37.04	10.4	462
„ 24-27	8,113	3.5	1,837.4	37.28	10.8	402
Aug. 14-17	9,888	11.1	2,047.1	39.03	10.5	421
Total	44,924	5.6	9,577.3	37.31	10.9	3,478

TABLE 33b.
(*Main Crop.*)

Date of picking.	Total pods harvested.	Per cent. pods discarded.	Wet weight in lbs. beans.	Per cent. dry/wet.	Pods per lb. dry.	Pods for seed.
Sept. 5-25	115,753	1.8	24,648.2	43.00	10.5	2,240
Oct. 14-18	115,439	3.5	22,544.2	41.75	11.7	1,149
„ 25-Nov. 9	81,744	3.2	14,805.2	42.04	12.2	2,687
Nov. 14-22	35,219	3.8	5,784.8	41.55	13.3	1,831
„ 29-Dec. 8	22,656	4.3	3,494.7	39.90	12.5	4,300
Dec. 14-Jan. 3	21,929	4.3	4,136.2	37.46	12.4	1,812
Jan. 9-17	11,167	5.7	2,090.2	36.79	12.9	629
„ 22-25	2,186	6.0	440.9	36.76	12.7	—
„ 30-Feb. 2	950	10.8	156.8	34.41	14.7	56
Feb. 12-16	710	12.0	121.0	34.67	14.2	31
Total	407,753	3.2	78,222.2	41.74	11.6	14,735
Grand Total	452,677	3.4	87,799.5	41.26	11.6	18,213

TABLE 34.

Light/Main Crop Seasons.

Figures for 1950/51, Compared with 13-Year Means, and 1949/50 Season (63.6875 Acre).

Period.	Total pods harvested.	Per cent. pods discarded.	Wet weight in lbs. beans.	Per cent. dry/wet.	Yield per acre in lbs. dry. *
Minor crop 1949/50	86,553	20.8	16,297.2	34.80	89.0
13-year mean	61,085	8.2	11,542.5	37.60	64.8
1950/51	44,924	5.6	9,577.3	37.30	61.1
Main crop 1949/50	364,535	4.2	77,660.0	39.27	478.9
13-year mean	514,897	8.7	92,826.1	41.80	583.3
1950/51	407,753	3.2	78,222.2	41.7	532.6
1949/50	451,088	7.4	93,957.2	38.50	567.9
Light/Main					
13-year mean	575,981	12.6	104,369.4	41.30	648.1
1950/51	452,677	3.4	87,799.5	41.26	593.7

* Includes pods used for seed, expressed as dry cacao.

The Distribution of Yield data on the 224 one-quarter acre plots of the Uniformity Trial Area is classified in Table 35.

The model class is as for the previous season, with 75 per cent. of the plots yielding more than 400 lbs. of dry cacao per acre.

TABLE 35.
Distribution of Plot Yield.

Yield class.	Percentage of total number of plots in each class.				
	1946/47.	1947/48.	1948/49.	1949/50.	1950/51.
0— 200	16.5	13.4	5.36	5.80	4.91
201— 400	34.8	38.0	13.84	20.09	20.09
401— 600	26.8	36.2	24.11	30.36	34.38
601— 800	15.6	8.9	24.55	25.00	22.77
801—1,000	4.9	3.1	18.30	16.27	12.05
1,001—1,200	0.9	0.4	8.93	2.23	4.46
1,201—1,400	—	—	4.46	0.45	1.34
1,401—1,600	0.5	—	0.45	—	5.00
1,601—1,800	—	—	—	—	—
Highest plot yield in lbs. per acre	1,527.60	1,051.48	1,485.60	1,252.84	1,381.32
Lowest plot yield in lbs. per acre	Nil.	Nil.	3.68	1.64	8.64

Warty Pods.

The number of pods bearing warts, expressed as a percentage of total pods harvested, was slightly higher than the previous season's figure.

A far greater percentage of the discarded pods were warty than in the 1949/50 crop.

TABLE 36.

Picking.	Warty pods.	Warty pods expressed as per cent. of total pods harvested.	Warty pods. discarded.	Discarded warty pods expressed as per cent. of warty pods harvested.
Minor... ..	990	2.2	195	19.7
Main	1,550	3.8	4,731	30.4
Total 1950/51	16,540	3.7	4,926	29.8
1949/50 ...	14,626	3.2	2,092	6.3

Tree Mortality.

The numbers of trees lost from swollen shoot disease and other causes showed an increase over the previous year.

24 seedlings and 393 mature trees were removed after diagnosis of swollen shoot disease and 302 mature trees died from drought, senility and other causes.

NEW ACQUISITION.

The minor and major crops were, as on the Old Station, more or less merged.

Yields of cacao were up by 15.4 per cent. on last season due in the main to young farms coming into bearing.

Pods losses were lighter at 4.1 per cent. compared with 7.7 per cent. in 1949/50.

B. FIELD EXPERIMENTS.

The growth of volunteer forest tree seedlings on the experimental areas has been most encouraging, and examination has shown that there are, in most areas, sufficient to provide shade without the necessity for planting. There exists a large number of species which should provide the requisite canopy at different levels.

Although a number of young cacao trees in the Amelonado plots have borne pods, none of the areas has, as yet, come into general bearing.

The Uniformity Trial.

The seedlings in this area have maintained a steady if somewhat slow growth. Shade trees have made excellent growth and are keeping well above the cacao.

The Establishment Trial.

The basket seedling treatment still maintains a marked superiority over all other treatments, these being the only plots containing bearing trees.

The Establishment Trial "B."

In this experiment planted in June, 1949, there has been little observable difference in the growth of the cacao, although in the early stages that under Tree Cassava appeared to flush more regularly.

There has also been a tendency for the rather dense shade in the traverses cut through the bush to repress the growth of the cacao. This will be remedied by the removal of the vines and monocotyledons during the coming rains.

The Spacing Trial.

It is as yet too early to assess the effects of the spacing treatments. Of 200 pods harvested 87 were from one treatment, but the numbers are too small for statistical analysis of the results.

The shade conditions, which had been poor following the removal of the banana hedges and severe tornado damage, have improved, the growth of indigenous tree seedlings being particularly good.

The Thinning Trial.

The seedlings in the closely spaced plots which have been thinned to 4 ft. $\times$ 4 ft. in the regular thinning treatment and to approximately that density in the "thinning by eye" treatment have lost their lanky appearance, but have not made such good overall growth as those planted at 8 ft. $\times$ 8 ft.

The Upper Amazon Type Spacing Trial.

The seedlings in this experiment, planted in June, 1949, have made excellent progress.

Several seedlings bore pods at 1½ years from planting as six-month-old basket plants.

The shade conditions are almost ideal as only senile forest trees were removed prior to planting, and only gaps in the existing shade canopy had to be filled with quick-growing trees.

Growth has been most rapid on the red clay soils at the top of the "catina" and in the clays of the Akwadum Soil Series in the valley bottom; with a falling-off in growth on the transported soils of the Nankese series on the slopes.

The growth of the Upper Amazon seedlings on the five acres contiguous to this area has been equally good, although the cacao was not planted until five months later.

The Amelonado Source Trial.

This experiment, designed to ascertain whether there has been any deterioration of the West African Amelonado stock was laid down and planted in May.

It is in the form of a randomised block of six replications of five treatments. Three of the treatments are planted with progeny of, as nearly as possible, the earliest introductions to West Africa, namely:—

- (1) Aburi trees planted in 1891, San Thomé origin.
- (2) Mampong trees reputed to have been grown from seed imported by Tettey Quashie, from Fernando Po, in 1879.
- (3) Trees on Ogunwole's Farm, Ibadan, Nigeria, planted 1887.

The two other treatments are planted with progeny of the youngest bearing Amelonado cacao obtainable, namely:—

- (4) Nankese Sub-Station trees planted in 1945.
- (5) Trees at Ijebu-Ode, Nigeria.

Shade conditions prior to planting were good and the seedlings have grown well.

Transplanting Experiments.

Experiments have been laid down, at W.A.C.R.I. and at Akwadum Sub-Station, to investigate means of successfully transplanting bare root seedlings approximately six months old. The treatments are the comparison of superphosphate at the rate of 1 oz. per square yard of nursery bed and no superphosphate in association with three kinds of treatment at transplanting time, *i.e.*, leaves removed; stumping back to 4 inches; or no treatment. 6 ft. $\times$ 6 ft. Latin Squares have been used in the layout.

To date germination and growth of the seedlings planted at the beginning of February has been better on the sandy soils at Akwadum than on the valley bottom clays at Tafo, and there are indications that the superphosphate application has decreased the dry weight of tops at W.A.C.R.I., but has had no effect on germination percentage, tap root length or root dry weight. Phosphate analysis of the plants is being undertaken by the Soil Scientist.

Performance of Cacao on Different Soil Types.

Replicated 12-tree plots have been selected on five of the soil types represented on the Old Station, namely, W.A.C.R.I., Koforidua, Nankese, Asafo, and Akwadum series.

Records of girths, flushing, flowering, pod growth, and yields will be taken and statistical analyses carried out to determine the variation between soil types and to estimate the extent of correlation with soil nutrient and moisture conditions; and eventually after several seasons to determine the effect of rainfall on yields on the different soil types.

Sampling Survey for the Forecasting of Cacao Yields.

Eighty one-fortieth of an acre plots have been selected on the Square Mile, and the trees numbered. Detailed records will be kept during the pod-growing and harvest periods in an attempt to find suitable independent variates showing high degrees of correlation with eventual total yield in any one season, thereby constituting an accurate means of forecasting the crop. Later it is hoped to apply the results on a Colony basis if sufficiently accurate results can be obtained here.

C. SWOLLEN SHOOT CONTROL.

The progress of the measures taken to keep the swollen shoot disease within economic bounds is summarised in Tables 37 and 38.

TABLE 37.

Month.	New outbreaks.	Trees destroyed.		Total.
		New outbreaks.	Old outbreaks.	
1950				
April	8	21	46	67
May	7	29	8	37
June	5	11	20	31
July	2	6	27	33
August	2	2	12	14
September	4	9	15	24
October	6	9	22	31
November	7	14	22	36
December	3	7	26	33
1951				
January	3	16	27	33
February	5	13	13	26
March	5	6	36	42
1950/51	57	143	274	417
1949/50	41	88	299	387

TABLE 38.

Swollen shoot Treatment.

Section.	Cacao destroyed during treatment.				Total.
	April-June.	July-Sept.	Oct.-Dec.	Jan.-Mar.	
A	466	189	120	115	890
B	218	122	89	143	572
C	126	40	68	78	312
D	164	90	80	28	362
Total	974	441	357	364	2,136

There was an increase in the number of outbreaks on the Old Station arbitrarily classed as new outbreaks, that is in localities where no disease has occurred for more than six months, which may be accounted for by spread from heavily infected mature farms along the boundary.

D. CACAO FERMENTATION.

A series of experiments, using 40 lb. samples of wet cacao beans, has been commenced.

The object of these experiments is to produce a fully fermented end-product, having no flat or purple (insufficiently fermented) beans yet retaining the characteristic flavour and aroma.

Types of cacao used have been West African Amelonado, Upper Amazon and the Selection E1.

Amelonado.

Indications are that :—

- (a) Fermentation in Solar Fermentaries gave higher temperatures during fermentation than in exposed boxes of the same size, but did not reduce the percentage of purple beans sufficiently.
- (b) Slow drying reduced the percentage of purple beans but did not eliminate them.
- (c) Small scale fermentations in boxes or baskets produced samples which compared favourably with those from bulk fermentations.
- (d) When the percentage of purple beans is reduced to any extent (8-day fermentation) there appears to be a deterioration in flavour and aroma.

Upper Amazons.

In comparison with Amelonado the mixed samples of Upper Amazon types have shown a slower rise in temperature during the first two days fermentation and a consistently higher percentage of under-fermented beans.

Selection E1.

Samples fermented under the same conditions as Amelonado have produced a high percentage of purple beans.

Bean Size.

A statistical examination of "bean counts per 11-oz. sample" and rainfall and humidity figures has been made and there are indications that the rainfall in the month prior to harvesting has a marked influence on the bean size, judging from records over the past crop season at Tafo. A small bean size at the height of this last main crop was associated with high rainfall during the preceding month.

E. MISCELLANEOUS.

Routine shade control and general maintenance has been conducted on the Clonal Plots of the Division of Pathology, The Herrania Multiplication Plot and Introductions Areas.

A considerable amount of Statistical work has been carried out for other Divisions, involving the analysis of data accumulated from work already done and the design of new experiments.

TAFO STATION : MAINTENANCE AND GENERAL.

Cacao seedlings planted in swollen shoot and other patches have been growing satisfactorily. Capsid control measures involving painting with D.D.T. emulsion were carried out regularly; in the Old Station 172,668 seedlings and in the Square Mile 227,035 young and seedling plants were painted during the year. Thinning of seedlings continued.

Sanitation work including removal of loranthus, dead and dying branches and light brushing was performed in regular periods.

Nurseries.

217 seedlings of the Upper Amazon type of cacao were issued for planting; 606 beans of Amelonado and 204 of T87 were sown for replacement purposes.

Food Crops.

About 10 acres of land unsuited to cacao were used for food crop cultivation. Yield of maize was poor due to rust disease.

5,333 lbs. of produce from the Vegetable Garden were sold as against 4,500 lbs. last year.

General.

Routine maintenance of roads and hedges, buildings and compounds continued.

Routine anti-malarial control measures were carried out regularly during the year.

APPENDIX I.—METEOROLOGICAL DATA.

RAINFALL APRIL, 1950-MARCH, 1951 (INCHES).

1. *Sub-Stations.*

	1950 April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	1951 Jan.	Feb.	Mar.	Mean.
Akwadum ...	4.53	4.89	4.15	5.17	0.51	2.06	10.58	4.21	1.41	0.34	1.26	11.08	50.19 51.40 6-yr.
Nankese ...	3.97	6.74	4.88	5.04	0.92	2.12	13.77	5.94	2.09	0.28	3.04	11.04	59.83 48.94 5-yr.
Koransang ...	5.32	7.15	5.38	1.86	2.42	2.97	9.54	3.99	0.55	2.83	1.67	7.60	51.28 54.81 "
Kukua ...	3.94	7.23	2.53	0.56	1.62	4.52	8.75	3.89	0.68	2.04	1.46	7.50	44.72 53.37 "
Adonkwanta ...	5.65	8.96	5.96	5.27	1.79	2.67	8.39	3.80	2.15	0.28	4.55	4.85	54.32 61.91 "

2. *Monthly Rainfall (in inches) and number of wet days—January, 1950—March, 1951, Tafo Station.*

	1950 Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	1951 Jan.	Feb.	Mar.
Rainfall in inches ...	6.24	5.22	7.36	8.71	7.25	4.54	3.38	0.97	4.39	8.17	3.87	3.37	0.29	5.48	4.45
Number of wet days ...	4	3	10	11	10	15	10	8	15	16	10	9	2	9	8

3. *Figures for 1950 Compared with 13-Year Means.*

	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Highest shade maximum 13-year mean	91.2	93.6	93.5	93.5	92.0	89.3	86.7	86.2	88.1	89.9	90.5	90.5
Highest shade maximum 1950 ...	91	96	94	98	92	90	87	86	90	89	91	91
Lowest shade maximum 13-year mean	58.4	61.5	65.8	66.0	66.7	66.3	66.8	65.6	66.3	66.4	64.9	62.5
Lowest shade maximum 1950 ...	58	58	64	67	66	61	70	68	54	65	63	66
Mean relative humidity 13-year mean...	86.0	83.7	81.6	81.1	81.7	84.6	85.7	85.7	84.6	82.7	81.5	83.9
Mean relative humidity 9.00 G.M.T. 1950	88.2	82.3	81.0	82.2	84.7	85.6	85.9	84.9	84.0	83.8	83.2	85.6
Mean relative humidity 13-year mean...	53.2	50.1	53.5	67.4	61.3	66.8	67.9	68.7	70.5	68.9	65.1	61.2
Mean relative humidity 15.00 G.M.T. 1950	59.6	46.8	60.1	65.6	68.1	70.5	72.9	70.2	69.6	65.5	65.4	63.9
Rainfall in inches 13-year mean	1.63	3.56	5.88	6.12	7.21	8.27	5.45	2.82	5.83	7.90	5.30	2.80
Rainfall in inches 1950 ...	6.24	5.22	7.36	8.71	7.25	4.54	3.38	0.97	4.39	8.17	3.87	3.37
Number of wet days 13-year mean	3.5	7.2	11.1	11.1	13.5	18.6	13.1	13.0	17.5	17.1	11.3	6.7
Number of wet days 1950 ...	4.0	3.0	10.0	11.0	10.0	15.0	10.0	8.0	15.0	16.0	10	9

4. *Annual Rainfall Figures, 1938/50.*

1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	13-year Mean.
55.33	84.96	56.92	56.59	59.45	69.09	49.12	68.87	47.03	67.30	66.99	71.81	63.47	62.86

APPENDIX II.

PUBLICATIONS.

- POSNETTE, A. F. and ROBERTSON, N. F. Virus Diseases of Cacao in West Africa.
VI.—Vector Investigations. *Annals of Applied Biology*, Vol. 37, No. 3, 1950.
- POSNETTE, A. F. ... VII.—Virus Transmission by Different
Vector Species. *Annals of Applied Biology*, Vol. 37, No. 3, 1950.
- MACLEAN, J. A. R. ... Single-Pod Fermentation of Cacao. *Nature*,
Vol. 166, 1950.

WEST AFRICAN CACAO RESEARCH INSTITUTE.

BALANCE SHEET AS AT 31ST MARCH, 1951.

SGSD. JOHN WEST, DIRECTOR OF CACAO RESEARCH.

We have audited the above Balance Sheet of the West African Cocoa Research Institute with the books and vouchers of the Institute and have obtained all the information and explanations that we have required. In our opinion and subject to our Report of even date attached hereto this Balance Sheet sets forth a true and correct view of the financial position of the Institute as at 31st March, 1951, according to the best of our information and the explanations given to us and as shown by the books of the Institute.

ACCRA, 18th June, 1951.

(SGD.) CASSETON ELLIOTT & CO.,
Auditors

